PREFACE

This report contains the findings of a water quality survey of Great East Lake located in Wakefield, New Hampshire and Acton, Maine. Sampling was conducted in the summer of 2009 by the University of New Hampshire **Center for Freshwater Biology (CFB)** in conjunction with the Great East Lake Improvement Association.

The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of the 2009 results as well as more detailed "Introduction" and "Discussion" sections. Graphic display of data is included, in addition to listings of data in appendices, to aid visual perspective.

ACKNOWLEDGMENTS

2009 was the twenty-third year the Great East Lake Improvement Association participated in the **New Hampshire Lakes Lay Monitoring Program (LLMP)**. The volunteer monitors involved in the water quality monitoring effort are highlighted in Table 1 while Charles Hodsdon again coordinated the volunteer monitoring activities on Great East Lake and acted as liaison to the **Center for Freshwater Biology (CFB)**. The **CFB** congratulates the volunteer monitors on the quality of their work, and the time and effort put forth. We invite other interested residents to join the Great East Lake water quality monitoring effort in 2010 and expand upon the current database. Funding for the water quality monitoring program was provided by the Great East Lake Improvement Association.

Table 1: Great East Lake Volunteer Monitors (2009)

Name
Charles & Marcia Hodsdon
Dave & Carol Lafond
Martin & Linda Schier

The **Center for Freshwater Biology** is a not-for-profit research program coordinated by Jeffrey Schloss and Robert Craycraft. Members of the **CFB** summer field team included William Finley, Gabrielle Hodgman, Lejla Kadic and Taylor Salas while Bethany Chester, Emma Leslie, Choe Shannon, Jessica Waller and Elizabeth Willey provided additional assistance in the fall analyzing, compiling and organizing the water quality data.

The **CFB** acknowledges the University of New Hampshire Cooperative Extension for funding and furnishing office and storage space while the College of Life Sciences and Agriculture provided laboratory facilities and additional storage space. The **CFB** would like to thank the **Caswell Family Foundation** for their continued generosity in providing long-term support for undergraduate assistantships while additional support for administering the **NH LLMP** comes from the **United States Department of Agriculture Cooperative State Research, Education and Extension Service** through support from the New England Regional Water Quality Program, (http://www.usawaterquality.org/newengland/).

Participating groups in the **LLMP** include: Acton-Wakefield Watershed Alliance, Green Mountain Conservation Group, North River Lake Monitors, the associations of Baboosic Lake, Bow Lake Camp Owners, Chocorua Lake, Conway Lake Conservation, Crystal Lake, Goose Pond, Great East Lake, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Lovell Lake, Mendums Pond, Merrymeeting Lake, Milton Ponds Lake Lay Monitoring, Mirror Lake (Tuftonboro), Moultonborough Bay, Lake Winnipesaukee, Naticook Lake, Newfound Lake, Nippo Lake, Silver Lake (Madison), Squam Lakes, Sunset Lake, Swains Lake, Lake Wentworth, Winnisquam Drive, and the towns of Alton, Amherst, Enfield, Madison, Meredith, Merrimack, Milton, Strafford and Wolfeboro.

Great East Lake Water Quality Monitoring 2009

Great East Lake remains one of Wakefield's natural resource assets providing recreational opportunities to the lakefront property owners, town residents and out of town visitors. Long-term water quality monitoring was instituted on Great East Lake to generate a database to which future water quality data could be compared, to identify potential problems around the lake and to proactively address water quality threats to the lake which will help ensure that Great East Lake remains a natural resource asset for future generations.

2009 Water Quality Data

Volunteer water quality monitoring has been ongoing in Great East Lake since 1987. In 2009, the volunteers collected weekly data during the "growing season" that spanned May 20 to September 26. The water quality monitoring focused on the collection of water quality data at four in-lake sampling locations that provide insight into the overall condition of Great East Lake.

Water transparency measurements are collected with a standardized eight inch diameter black and white disk that is lowered into the water column until it can no longer be seen. The Great East Lake water transparency measurements remained high throughout the summer months and included a maximum visibility of approximately 40.0 feet (12.2 meters) that was documented on September 10, 2009. The 2009 Great East Lake water clarity data continued to exhibit some of the higher water transparency measurements that have been documented among our New Hampshire Lakes.

The amount of microscopic plant growth (visually detectible as golden or green water) generally remained low through the summer months and remained well below nuisance levels. The corresponding phosphorus (nutrient) concentrations were low to moderate at each of the Great East Lake sampling locations and corresponded to the low to moderate levels of algal growth. The microscopic plant samples collected in the most embayed (isolated) sampling location were significantly higher than the corresponding samples that were collected at the more open water sampling locations.

Dissolved oxygen concentrations, required for a healthy fishery, remained high throughout the water column at the open water sampling sites and remained well within the optimum range for coldwater fish species such as rainbow trout and salmon.

Common Concerns among New Hampshire Lakes

Many lakeshore property owners throughout New Hampshire express concerns that increased aquatic plant "weed" growth and the amount of slime that coats the lake bottom in the shallows has been steadily increasing over the years. While sufficient data have not been generated to quantitatively support these assertions, communications from Great East Lake monitors and camp owners indicate these are also common concerns for their lake. As the lakeshore and the surrounding uplands are converted from a well forested landscape to a more suburbanized setting, more nutrients oftentimes enter the lake and in turn promote plant growth. Keep in mind, the same nutrients that stimulate growth of our lawns will also stimulate growth in our lakes. Nutrients can originate from a number of sources within the Great East Lake watershed that include septic system effluent, lawn fertilizer runoff and sediment washout. While some nutrient loading will occur naturally even in our most remote New Hampshire lakes, there are steps you can take to minimize nutrient runoff, that increases microscopic plant growth (greenness), contributes to the slimy coatings we find on rocks along our beaches and allows for new, or the expansion of, existing weed beds in the shallows of Great East Lake.

10 Recommendations for Healthy Lakeshore and Streamside Living

Given the concerns discussed above make sure you consider the following recommendations and spread the word to your lake association and neighbors.

1. <u>Encourage shoreside vegetation and protect wetlands</u> - Shoreside vegetation (also known as **riparian vegetation**) and wetlands provide a protective buffer that "traps" pollutants before reaching the lake. These buffers remove materials both chemically (through biological uptake) and physically (settling materials out). As riparian buffers are removed and wetlands lost, pollutant materials are more likely to enter the lake and in turn, favor declining water quality. Shoreline vegetation grown tall will also discourage geese and shade the water reducing the possibility of aquatic weed recruitment including the dreaded invasive milfoil.

2. <u>Limit fertilizer applications</u> - Fertilizers entering the lake can stimulate aquatic plant and algal growth and in extreme cases result in noxious algal blooms. Increases in algal growth tend to diminish water transparency and under extreme cases culminate in surface "scums" that can wash up on the shoreline and can also produce unpleasant smells as the material decomposes. Excessive nutrient concentrations also favor algal forms known to produce toxins which irritate the skin and under extreme conditions, are dangerous when ingested. Use low maintenance grasses such as fescues that require less nutrients and water to grow. Do not apply any fertilizers until you have had your soils tested. Oftentimes a simple pH adjustment will do more good and release nutrients already in the soils. After a lawn is established a single application of fertilizer in the late fall is generally more than adequate to maintain a healthy growth.

3. <u>Prevent organic matter loading</u> - Excessive organic matter (leaves, grass clippings, etc.) are a major source of nutrients in the aquatic environment. As the vegetative matter decomposes nutrients are "freed up" and can become available for aquatic plant and algal growth. In general, we are not concerned with this material entering the lake naturally (leaf senescence in the fall) but rather excessive loading of this material as occurs when residents dump or rake leaf litter and grass clippings into the lake. This

material not only provides large nutrient reserves which can stimulate aquatic plant and algal growth but also makes great habitat for leaches and other potentially undesirable organisms in swimming areas.

4. Limit the loss of vegetative cover and the creation of impervious surfaces - A forested watershed offers the best protection against pollutant runoff. Trees and tall vegetation intercept heavy rains that can erode soils and surface materials. The roots of these plants keep the soils in place, process nutrients and absorb moisture so the soils do not wash out. Impervious surfaces (paved roads, parking lots, building roofs, etc.) reduce the water's capacity to infiltrate into the ground, and in turn, go through nature's water purification system, our soils. As water seeps into the soil, pollutants are removed from the runoff through absorption onto soil particles. Biological processes detoxify substances and/or immobilize substances. Surface water runoff over impervious surfaces also increases water velocities which favor the transport of a greater load of suspended and dissolved pollutants into your lake.

5. Follow the Flow - Try to landscape and re-develop with consideration of how water flows on and off your property. Divert runoff from driveways, roofs and gutters to a level vegetated area or a rain garden so the water can be slowed, filtered and hopefully absorbed as recharge.

6. Discourage the feeding ducks and geese - Ducks and geese that are locally fed tend to concentrate in higher densities around the known food source and can result in localized water quality problems. Waterfowl quickly process food into nutrients that are capable of stimulate microscopic plant "algal" growth. Ducks and Geese are also host to the parasite responsible for swimmers itch. While not a serious health threat, swimmers itch is very uncomfortable especially for young children.

7. Maintain septic systems - Faulty septic systems are a big concern as they can be a primary source of water pollution around our lakes in the summer. Septic systems are loaded with nutrients and can also be a health threat when not functioning properly. Inspect your system on a timely basis and pump out the septic tank every three to five years depending on tank capacity and household water use. Since the septic system is such an expensive investment often costing around $10,000 for a complete overhaul, it is advantageous to assure proper care is taken to prolong the system's life. Additionally, following proper maintenance practices will reduce water quality degradation.

8. Take care when using and storing pesticides, toxic substances and fuels as it only takes a small amount to pollute lake, stream and ground water.

9. Stabilize access areas and beaches - Perched beaches (cribbed areas) that keep sand and rocks in-place are preferred if you have to have that type of access. Do not create or enhance beach areas with sand (contains phosphorus, smothers aquatic habitat, fills in the lake as it gets transported away by currents and wind).

10. Review the updated New Hampshire Comprehensive Shoreland Protection Act (CSPA) if you have shoreland property. The CSPA sets legal regulations aimed at protecting water quality. If you have any questions regarding the act or need further information contact the Shoreline Protection Act Coordinator at (603) 271-3503.

Note: Consult materials such as those listed below, for further guidance on assessing and implementing corrective actions that can maintain or improve the quality of surface and subsurface (septic) runoff that may otherwise impact water quality.

- Pipeline: Summer 2008. Vol. 19, No. 1. Septic Systems and Source Water Protection: Homeowners can help improved community water quality. http://www.nesc.wvu.edu/pdf/WW/publications/pipline/PL_SU08.pdf
- Landscaping at the Water's Edge: an Ecological Approach. $20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824. http://extension.unh.edu/resources/
- Integrated Landscaping: Following Nature's Lead. $20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824. http://extension.unh.edu/resources/
- The Best Plants for New Hampshire Gardens and Landscapes - How to Choose Annuals, Perennials, Small Trees & Shrubs to Thrive in Your Garden. University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824. http://extension.unh.edu/resources/
- Buffers for Wetlands and Surface Waters: A Guidebook for New Hampshire Municipalities. Audubon Society of New Hampshire. http://www.nh.gov/oep/resourcelibrary/documents/buffershandbook.pdf
- New Hampshire Department of Environmental Services fact sheet series (all topics) http://des.nh.gov/organization/commisioner/pip/factsheets/index.htm

Great East Lake
2009 Executive Summary

Water quality data were collected by the Great East Lake volunteer monitors between May 20 and September 26, 2009 at four in-lake sampling locations (Figure 9). Supplemental water quality data were collected by the University of New Hampshire **Center for Freshwater Biology** on September 10, 2009 at the deep sampling sites, Sites 1 Center, 2 Canal Basin, 3 Maine Mann and in the 2nd Basin. Generally speaking, the 2009 Great East Lake water quality remained excellent as summarized in Table 2. The Great East Lake water transparency was high and averaged 29.5 feet (9.0 meters) among the four sampling stations while the average chlorophyll *a* concentration (a measure of microscopic plant "algal" growth) and the 2009 total phosphorus concentrations were generally low and generally remained within the range considered typical of an unproductive "pristine" New Hampshire Lake (Table 2).

Table 2: 2009 Great East Lake Seasonal Average Water Quality Readings and Water Quality Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.

Parameter	Oligotrophic "Pristine"	Mesotrophic "Transitional"	Eutrophic "Enriched"	Great East Lake Average (range)	Great East Lake Classification
Water Clarity (meters)	> 4.0	2.5 - 4.0	< 2.5	# 9.0 meters (range: 4.6 – 12.2)	Oligotrophic
Chlorophyll a (ppb)	< 3.0	3.0 - 7.0	> 7.0	# 1.5 ppb (range: 0.6 – 4.4)	Oligotrophic
Phosphorus (ppb)	< 15.0	15.0 - 25.0	> 25.0	* 8.2 ppb (range: 4.0– 15.6)	Oligotrophic

 # data from shallow site 3rd Basin omitted from summary
** Total Phosphorus data reported in Table 2 were collected in the surface waters (epilimnion) by the volunteer monitors.*

The following section discusses the 2009 and historical Great East Lake water quality data. *Refer to Appendix A for a complete listing of the 2009 Great East Lake water quality data and refer to Appendix B for an overview of the Box and Whisker plots that are referenced in this section.*

1) Water Clarity (measured as Secchi Disk transparency) – The 2009 Great East Lake water clarity values were consistently visible in excess of 4 meters, that is considered the boundary between an unproductive "pristine" and more nutrient enriched "transitional" New Hampshire lake, at the four sampling stations: Sites 1 Center, 2 Canal Basin, 3 Maine Mann and the 2nd Basin (Table 3 and Figures 10 - 17 & 20).

Table 3: 2009 Water Clarity data summary for the Great East Lake deep sampling stations.

Site	Seasonal Average Water Transparency (meters)
1 Center	10.4 meters (range: 9.2 – 12.2)
2 Canal	10.4 meters (range: 9.0 – 11.2)
3 MMann	9.7 meters (range: 8.7 – 10.5)
2nd Basin	5.5 meters (range: 4.6 – 6.0)

An inter-site comparison among the four Great East Lake sampling locations, Sites 1 Center, 2 Canal, 3 Maine Mann and the 2nd Basin, indicates the water was clearer at the more open water centrally located sampling sites, Site 1 Center, 2 Canal and 3 Maine Mann, and least clear at the most embayed of the sampling sites, the 2nd Basin (Figure 20).

The 2009 Great East Lake, Sites 1 Center, 2 Canal Basin, 3 Maine Mann and 2nd Basin, Secchi Disk transparency data remained well within the range of historical water quality measurements that have been documented since volunteer water quality was instituted on Great East Lake in 1987 (Figure 18, 20, 22 and 24).

2) Microscopic plant, algal, abundance "greenness" (measured as chlorophyll *a*) – The 2009 Great East Lake chlorophyll *a* concentrations generally remained below the concentration of 3 parts per billion (ppb) that is considered the boundary between a nutrient poor and more nutrient enriched "greener" lake (Figures 10, 12, 14, 16 & 21). Only the 2nd Basin sampling location, the most embayed of the sampling sites, included chlorophyll *a* concentrations that reached levels considered more typical of a moderately productive, greener, lake (Tables 2 & 4 and Figure 21).

Table 4: 2009 Chlorophyll *a* data summary for the Great East Lake deep sampling stations.

Site	Seasonal Average Chlorophyll *a* (ppb)
1 Center	1.1 ppb (range: 0.7 – 1.7)
2 Canal	1.3 ppb (range: 0.9 – 2.6)
3 Mmann	1.0 ppb (range: 0.8 – 1.5)
2nd Basin	2.4 ppb (range: 0.6 – 4.4)

An inter-site comparison among the four Great East Lake sampling locations indicates the median chlorophyll *a* concentrations were lower (i.e. less algal greenness) at Sites 1 Center, 2 Canal and 3 MMann and highest (i.e. greenest water) at the 2nd Basin sampling location (Figure 21).

The 2009 median chlorophyll *a* concentration documented at Sites 1 Center, 2 Canal Basin, 3 Maine Mann and 2nd Basin remained within the range of historical values documented since volunteer water quality monitoring was initiated on Great East Lake in 1987 (Figures 19, 21, 23 and 25). No new chlorophyll *a* minimum or maximum values were documented during the 2009 sampling season.

3) Background (dissolved) water color : often perceived as a "tea" color in more highly stained lakes – The 2009 Great East Lake dissolved color concentration averaged 8.2 chloroplatinate units (cpu) and fell within the classification of a slightly tea colored "clear" lake (Table 5). Dissolved color, or true color as it is sometimes called, is indicative of dissolved organic carbon levels in the water (a by-product of microbial decomposition). Small increases in water color from the natural breakdown of plant materials in and around a lake are not considered to be detrimental to water quality. However, increased

Table 5. Dissolved Color Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.

Range	Classification
0 - 10	Clear
10 - 20	Slightly colored
20 - 40	Light tea color
40 - 80	Tea colored
> 80	Highly tea colored

color can lower water transparency, and hence, change the public perception of water quality.

4) Total Phosphorus: the nutrient considered most responsible for elevated microscopic plant growth in our New Hampshire Lakes. - Total phosphorus concentrations, measured in the surface waters (epilimnion), were generally low to moderate when measured by the Great East Lake volunteer monitors during the 2009 sampling season and ranged from 4.0 to 15.6 parts per billion; ppb (Tables 2 and 6). The 2009 Great East Lake total phosphorus concentrations were generally near or below the concentration of 15 ppb that is considered the boundary between an unproductive and a moderately productive New Hampshire lake. Higher total phosphorus concentrations were documented in the more embayed, 2nd Basin, sampling station relative to the other sites (Table 6).

Table 6: 2009 Total Phosphorus data summary for the Great East Lake deep sampling stations.

Site	Seasonal Average Total Phosphorus (ppb)
1 Center	7.3 ppb (4.0 – 12.1)
2 Canal	5.9 ppb (4.1 – 7.2)
3 MMann	8.3 ppb (4.6 – 13.2)
2nd Basin	11.1 ppb (6.7 – 15.6)

5) Resistance against acid precipitation (measured as total alkalinity) – The 2009 Great East Lake alkalinity of 6.5 milligrams per liter (mg/l) is characteristic of a lake with a moderate vulnerability to acid precipitation according to the standards developed by the New Hampshire Department of Environmental Services (Table 7). Generally speaking, the geology of the region does not contain the mineral content (e.g. limestone) which increases the buffering capacity in our surface waters. Thus, lakes in the vicinity (i.e. Ossipee Lake and Wentworth Lake) have naturally low alkalinities.

Table 7. Alkalinity Classification Criteria used by the New Hampshire Department of Environmental Services

Range	Classification
< 0	Acidified
0 -2	Extremely Vulnerable
2.1 - 10.0	Moderately Vulnerable
10.1 - 25.0	Low Vulnerability
> 25.0	Not Vulnerable

6) Dissolved salts: measured as specific conductivity – Specific Conductivity levels, documented in Great East Lake were low and ranged from 60.0 to 62.0 micro-Siemans (uS) when measured at the deep, open water, sampling stations: Sites 1 Center, 2 Canal and 3 Maine Mann (Appendix A). Specific Conductivity was more variable at the more encoved second basin sampling location where the specific conductivity ranged from 57.0 to 88.0 uS and increased near the lakebottom. High specific conductivity values can be an indication of problem areas around a lake where failing septic systems, heavy fertilizer applications and sedimentation contribute "excessive" nutrients that make their way into Great East Lake. High specific conductivity values can also be associated with road salt runoff that is flushed into our New Hampshire Lakes.

7) **Temperature and dissolved oxygen profiles** – Temperature profiles collected by the volunteer monitors indicate Great East Lake becomes stratified into three distinct thermal layers during the summer months; a warm upper water layer, the **epilimnion**, overlies and a deep cold-water layer, the **hypolimnion**. The upper and lower layers are separated by a zone of rapidly decreasing temperatures, the **thermocline.** The formation of thermal stratification limits the replenishment of oxygen in the deeper waters and under adverse conditions can result in oxygen depletion near the lake-bottom.

Dissolved oxygen concentrations required for a healthy fishery – Dissolved oxygen concentrations documented by the **Center for Freshwater Biology** and volunteers remained high at Sites 1 Center, 2 Canal Basin, 3 Maine Mann and the 2nd Basin (Appendix A). With the exception of the 2nd Basin and 2 Canal Basin, the dissolved oxygen concentrations documented at the aforementioned sites remained well above the concentration of 5 milligrams per liter that is considered the minimum oxygen concentration required for the successful growth and reproduction of most coldwater fish that include lake trout and salmon. Current and historical data indicate the dissolved oxygen concentrations remain high in the deep, cold, waters and are capable of supporting a cold water fishery in Great East Lake (Sites 1 Center, 2 Canal Basin and 3 Maine Mann). The shallower and warmer waters that are characteristic of the 2nd Basin suggest that this segment of the lake is best suited for a warm water fishery.

8) Based on the current and historical water quality data, Great East Lake would be considered an unproductive "pristine" New Hampshire lake. However, continued development around the lake, heavy fertilizer applications and aging septic systems pose a threat to the high water quality characteristic of Great East Lake, particularly when local landowners do not take the appropriate precautions to minimize the transport of pollutants (i.e. sediments and the nutrient phosphorus) into the lake. Thus, a first step towards preserving high water quality in Great East Lake is to take action at the local level and do your part to minimize the number of pollutants that enter the Lake. Whenever possible, **maintain riparian buffers** (vegetative buffers adjacent to the water body). These buffers will biologically "take up" nutrients before they enter the lake and will also provide physical filters which allow materials to settle out before reaching the lake. Preserving buffer strips and avoiding shorefront disturbance also reduces the potential for aquatic plant colonization, including variable milfoil and other invasive weeds. No area is immune to the infestation of invasive weeds like milfoil, but plants are less likely to root in undisturbed shoreline areas. The retention of riparian buffers should be considered for both Great East Lake as well as the stream inlets that are responsible for the majority of the overland runoff that enters the Lake. **Reduce fertilizer applications**. Most residents apply far more fertilizers than necessary which can be a costly expense to the homeowner and can also be detrimental to the lake since the same nutrients that make our lawns green will also stimulate plant growth in our lakes. **Make sure your septic system is well maintained** and have it pumped out on a

regular basis. An improperly functioning septic system can contribute "excessive" nutrients into the lake and result in early failure, costing thousands of dollars to repair or replace. Future volunteer monitoring efforts should be directed at pinpointing problematic regions around the lake where corrective and educational efforts should be focused.

COMMENTS AND RECOMMENDATIONS

1) We recommend that each participating lake association, including the Great East Lake Association, continue to develop its database on lake water quality through continuation of the long-term monitoring program. The database currently provides information on the short-term and long-term cyclic variability that occurs in Great East Lake while continued monitoring would enable more reliable predictions of both short-term and long-term water quality trends.

2) We suggest interested residents and public officials review the Salmon Falls Headwater Lakes Watershed Management Plan, http://www.awwatersheds.org/images/stories/SFHeadwaterLakesWMP_April2010.pdf. The document includes a summary of the Great East Lake water quality, identifies threats to Great East Lake and provides suggestions aimed at minimizing future water quality degradation through a watershed management approach that encompases the entire Great East Lake drainage basin.

3) We recommend continued early season sampling (April/May) to document Great East Lake's reaction to the nutrient and acid loadings that typically occur during and after spring thaw. Sampling should include alkalinity, chlorophyll *a*, dissolved color, Secchi Disk transparency and total phosphorus measurements.

4) Frequent "weekly" water quality samples, necessary to assess the current condition of Great East Lake, should continue to be collected whenever possible. Continued sampling of chlorophyll *a*, Secchi Disk transparency, dissolved color, alkalinity and total phosphorus samples will be useful to track variations in nutrient loading during the summer months.

5) Some lakes have expanded their monitoring programs to include supplemental near-shore sampling locations that would help screen for problem areas and, when problems are identified, would help target resources (i.e. money and volunteer hours) to the most critical areas within the watershed where future monitoring and corrective efforts should be directed. Expanded water quality monitoring could be as simple as collecting additional near-shore/tributary total phosphorus or chlorophyll *a* samples or expanded water quality monitoring could involve the collection of additional water quality parameters such as dissolved oxygen and specific conductivity measurements. Advanced water quality monitoring efforts might also include more in-depth shoreline/watershed surveys aimed at visually identifying the land-use patterns and potential problem areas within the drainage basin. If you are interested in discussing additional water

quality monitoring options that would meet your needs please contact Bob Craycraft @ 862-3696 or via email, bob.craycraft@unh.edu.

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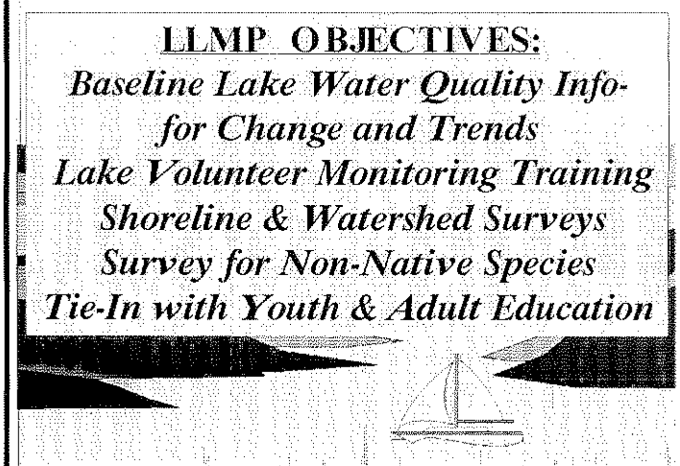
INTRODUCTION

The New Hampshire Lakes Lay Monitoring Program

The 2009 sampling season marked the thirty-first anniversary for the **NH Lakes Lay Monitoring Program (LLMP).** The **LLMP** has grown from a university class project on Chocorua Lake and pilot study on the Squam Lakes to a comprehensive state-wide program with over 500 volunteer monitors and more than 100 lakes participating. Originally developed to establish a database for determining long-term trends of lake water quality for science and management, the program has expanded by taking advantage of the many resources that citizen monitors can provide (Figure 1).

Figure 1. LLMP Objectives



The **NH LLMP** has gained an international reputation as a successful cooperative monitoring, education and research program. Current projects include: the use of volunteer generated data for non-point pollution studies using high tech analysis system (Geographic Information Systems and Satellite Remote Sensing), and intensive watershed monitoring for the development of watershed nutrient budgets, investigations of water quality impacts, including the formation of blue green bacteria blooms, associated with land use changes.

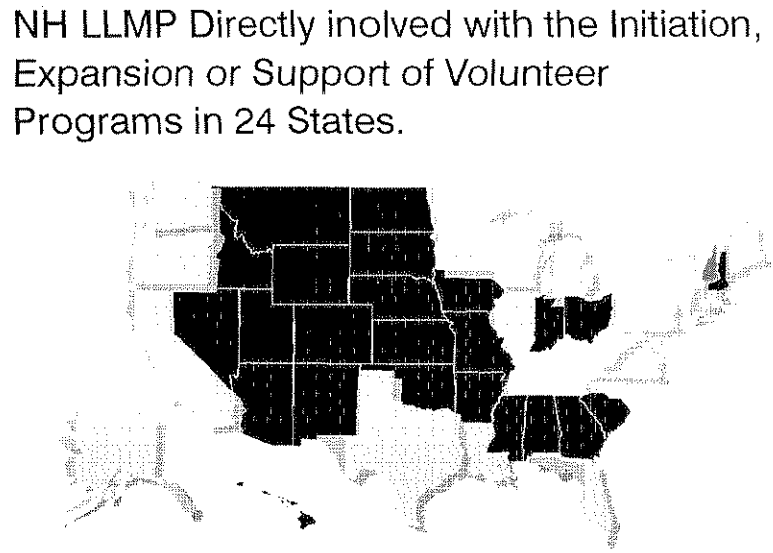
The key ingredients responsible for the success of the program include innovative cost share funding and cost reduction, assurance of credible data, practical sampling protocols and, most importantly, the interest and motivation of our volunteer monitors.

The 2009 sampling season was another exciting year for the **New Hampshire Lakes Lay Monitoring Program.**

Table 5. Awards & Recognition

1983-	NH Environmental Law Council Award
1984-	Governor's Volunteer Award
1985-	CNN Science & Technology Today
1988-	Governor's "Gift" award funded
1990-	NH Journal TV coverage NHPTV
1991-	Renew America Award Environmental Success Index White House Reception / Briefing
1992-	EPA Administrators Award
1993-	NH Lakes Association Award
1994-	EPA Office of Watersheds Award
1995-	Winnipesaukee Watershed Project
1998-	Governor's Proclamation for 20th Anniversary
1999-	EPA Watershed Academy Host
2001-	Lake Chocorua Project highlighted at national conferences (invited presentations)
2002-	Chocorua Project receives Technical Excellence Award from the North American Lake Management Society
2003-	UNH CE Maynard and Audrey Heckel Extension Fellowship awarded to LLMP
2004-	Participatory Research Model of NH LLMP highlighted at National Water Quality Monitoring Conference
2005-	LLMP Coordinator J. Schloss receives the prestigious Secchi Disk Award from the North American Lakes Management Society
2007-	Lake friendly landscaping manual introduced receives praise from New Hampshire agencies and waterfront landowners.
2008-	NH LLMP's 30th year of sampling NH lakes!
2009-	EPA Equipment support grant to the NH LLMP.

Figure 2. National LLMP Support to Volunteer Monitoring Programs



Light gray shading denotes LLMP assisted states

National recognition for the high quality of work by you, the volunteer monitors, culminated with program awards, requests for program information and invitations to speak at national conferences (Table 5).

The LLMP was part of a three year model watershed planning project, that was completed in 2009 and that encompassed the nearly 60,000 acre Newfound Watershed. The UNH CFB led the water quality sampling design and monitoring component of the project while project partners from Plymouth State University, Jeffrey Taylor and Associates, the Newfound Lake Region Association, etc. provided technical assistance in other program areas (land use planning, survey design and interpretation, project management) that culminated in the watershed wide planning effort that is aimed at protecting the Newfound lake and stream quality. The success of the watershed planning project has been highlighted as a model effort in New Hampshire and has led to a second round of funding, and expansion of project partners, that will facilitate further efforts to work with local landowners to protect the high quality Newfound waters, http://www.newfoundlake.org/watershedmasterplan.html. We are also excited by the continued results of teaming up students, educators and local lake residents through our Multidisciplinary Lakes Management course and our summer Watershed Ecology course that are held annually (the course for educators, community leaders and other interested persons). Some of the lake management recommendations made as part of the student coursework requirements have been successfully implemented by lake associations.

Our active collaboration with the UNH Center for Freshwater Biology continues to drive relevant applied research: The CFB was involved in supporting the zooplankton analysis for regional and national lake surveys.

We continue the research initiated by collaborators Dr. John Sasner and Dr. Jim Haney focusing on how watershed development and our activities on the landscape play a role in creating potentially toxic plankton blooms. Analogous to the 'red tide" of estuaries, certain blue-green bacteria (microscopic bacteria that are very much like algae) can produce toxins that are heath risks to animals and humans.

Additional ongoing research is focusing on the use of satellite and aerial imagery as well as on-lake optical devices as a means of determining the water transparency and amount of microscopic plant "algal" growth in our New Hampshire Lakes, particularly blue green algae. Water quality data, collected by the volunteer monitors, have served as ground truthed data to assess whether or not the satellite imagery shows promise. Data generated through this project have been presented at national conferences and are testament to the high quality data generated by our volunteer monitors.

Recent interest in the success of our NH LLMP participatory science research model has resulted in invited presentations at national conferences and provided the basis of a series of articles in the Volunteer Monitor, the national newsletter with a distribution of over 10,000. We continue to be listed as a model citizen-monitoring program on the Environmental Success Index of Renew America, the Environmental Network Clearinghouse and the National Awards Council for Environmental Sustainability. To date, the approach and methods of the **NH LLMP** have been adopted by new or existing programs in twenty-four states and eleven countries (Figure 2)!

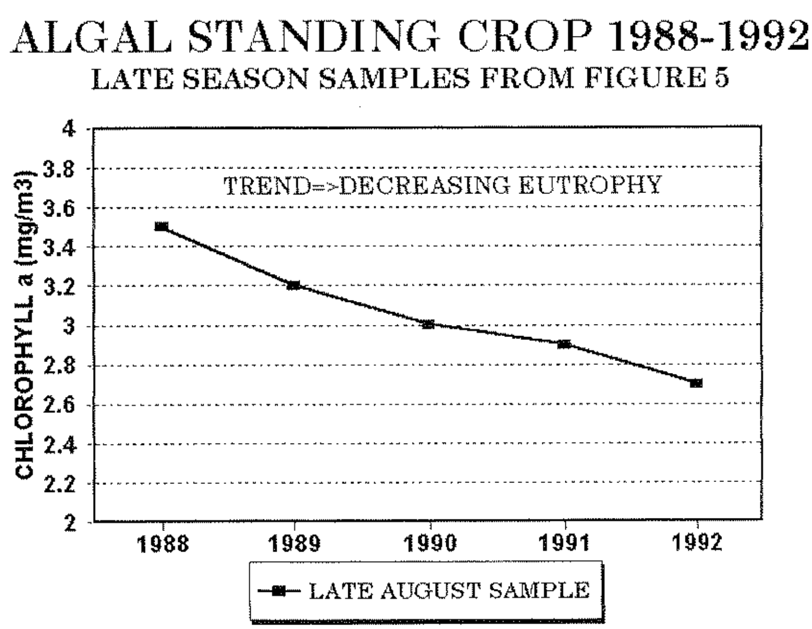
Importance of Long-term Monitoring

A major goal of our monitoring program is to identify any short or long-term changes in the water quality of the lake. Of major concern is the detection of cultural eutrophication: increases in the productivity of the lake, the amount of algae and plant growth, due to the addition of nutrients from human activities. Changes in the natural buffering capacity of the lakes in the program is also a topic of great concern, as New Hampshire receives large amounts of acid precipitation, yet most of our lakes contain little mineral content to neutralize this type of pollution.

For over two decades, weekly data collected from lakes participating in the **New Hampshire Lakes Lay Monitoring Program** have indicated there is quite a variation in water quality indicators through the open water season (April through November) on the majority of lakes. Short-term differences may be due to variations in weather, lake use, or other chance events. Monthly sampling of a lake during a single summer provides some useful information, but there is a greater chance that important short-term events such as algal blooms or the lake's response to storm run-off will be missed. These short-term fluct-uations may be unrelated to the actual long-term trend of a lake or they may be indicative of the changing status or "health" of a lake.

Consider the hypothetical data depicted in Figure 3. Limiting sampling of only once a year during August, from 1988 to 1992, produced a plot suggesting a decrease in eutrophication. However, the actual long-term term trend of the lake, increasing eutrophication,

Figure 3.



can only be clearly discerned by frequent sampling over a ten-year period (Figure 4). In this instance, the information necessary to distinguish between short-term fluctuations, the "noise", and long-term trends, the actual "signal", could only be accomplished through the frequent collection of water quality data over many years. To that end, the establishment of a long-term database was essential to determining trends in water quality.

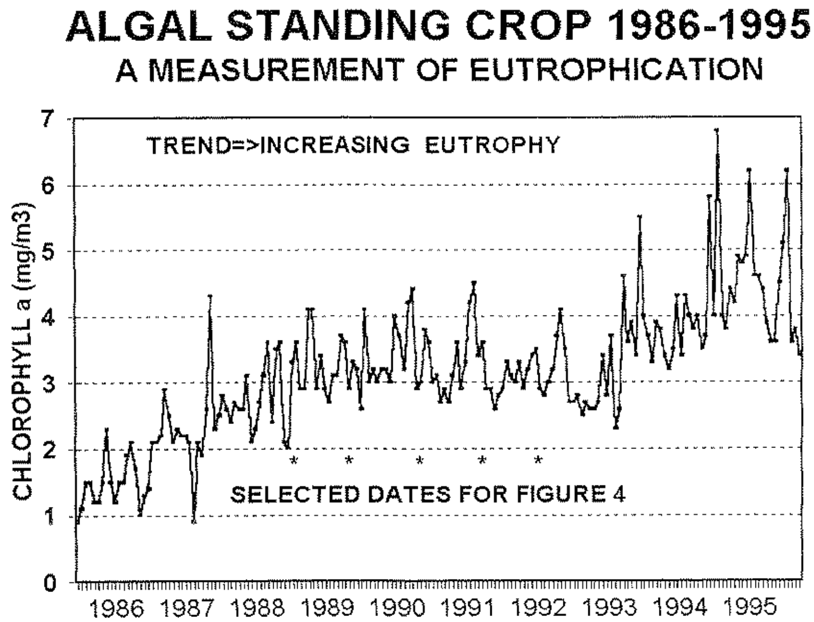


Figure 4

The number of seasons it takes to distinguish between the "noise" and the signal is not the same for each lake. Evaluation and interpretation of a long-term database will indicate that the water quality of the lake has worsened, improved, or remained the same. In addition, different areas of a lake may show a different response. As more data are collected, predictions of current and future trends can be made. No matter what the outcome, this information is essential for the intelligent management of your lake.

There are also short-term uses for lay monitoring data. The examination of different stations in a lake can disclose the location of specific problems and corrective action can be initiated to handle the situation before it becomes more serious. On a lighter note, some associations post their weekly data for use in determining the best depths for finding fish!

It takes a considerable amount of effort as well as a deep concern for one's lake to be a volunteer in the **NH Lakes Lay Monitoring Program**. Many times a monitor has to brave inclement weather or heavy boat traffic to collect samples. Sometimes it seems that one week's data does not differ from the next week's data, but every sampling provides important information on the variability of the lake.

We are pleased with the interest and commitment of our Lay Monitors and are proud that their work is what makes the **NH LLMP** the most extensive, and we believe, the best volunteer program of its kind.

Purpose and Scope of This Effort

The primary purpose of annual lake reporting is to discuss results of the current monitoring season with emphasis on current conditions of New Hampshire lakes including the extent of eutrophication and the lakes' susceptibility to increasing acid precipitation. If you have additional water quality concerns, we advise the lake association to contact our program staff to discuss additional monitoring options. When applicable we also strive to place the recent results into a historical context using past NH LLMP data as well as historical data from other sources. This information is part of a large data base of historical and more recent data compiled and entered onto our computer files for New Hampshire lakes that include New Hampshire Fish and Game surveys of the 1930's through the 1950's, the surveys conducted by the New Hampshire Water Supply and Pollution Control Commission and the **CFB/FBG** surveys. However, care must be taken when comparing current results with early studies. Many complications arise due to methodological differences of the various analytical facilities and technological improvements in testing.

Climatic Summary - 2009

Water Quality and the Weather

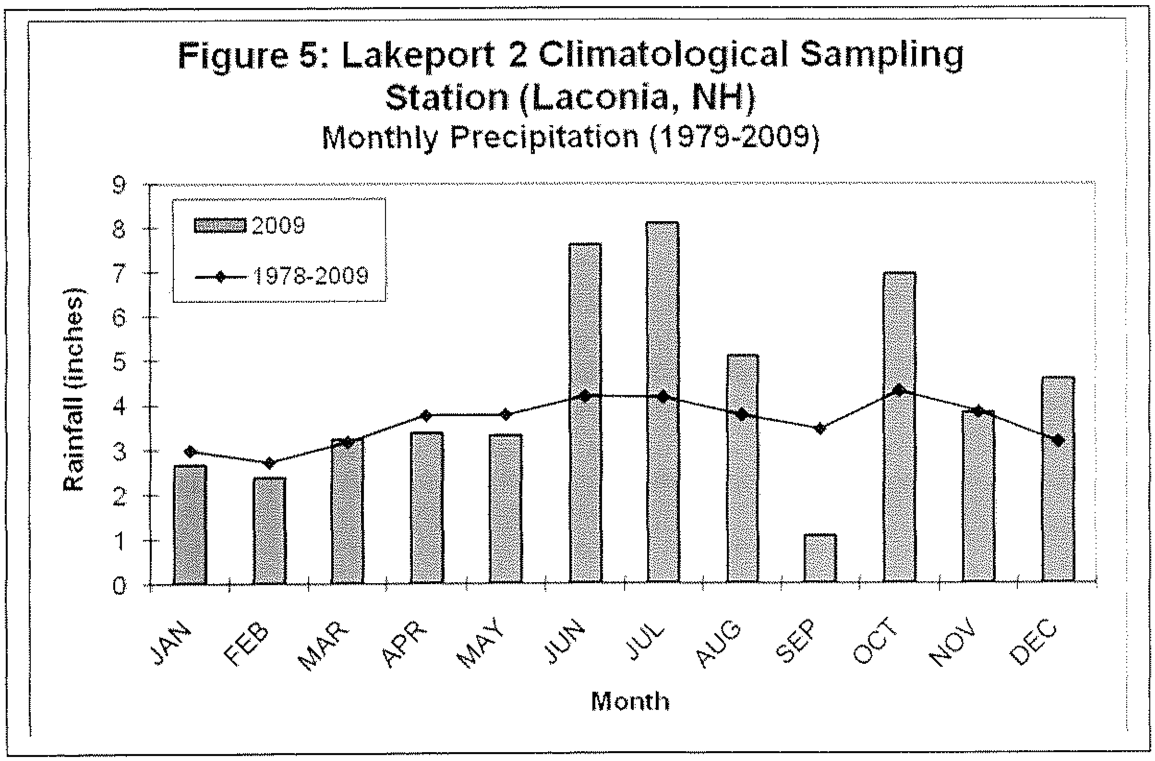
Water quality variations are commonly observed over the course of the year and among years in our New Hampshire lakes, ponds, wetlands and streams. The most commonly noticed changes are those associated with decreasing water clarities, increasing algal growth (greenness), and increasing plant growth around the lake's periphery. Over the long haul, changes such as these are attributed to a lake's natural aging process that is referred to as **eutrophication**. However, short-term water quality changes such as those mentioned above are often encountered even in our most pristine lakes and ponds. These water quality changes often coincide with variations in weather patterns such as precipitation and temperature fluctuations, and even variations in the sunlight intensity which can accelerate or suppress the photosynthetic process.

Climatic "swings" can have a profound effect on water quality, sometimes positive and other times negative. For instance, 1996 was a wet year relative to other years of **LLMP** water quality monitoring. The wet conditions translated into reduced water clarities, elevated microscopic plant "algal" growth and increased total phosphorus concentrations for most participating **LLMP** lakes. "Excessive" runoff associated with wet periods often facilitates the transport of pollutants such as nutrients (including phosphorus), sediment, dissolved colored compounds, as well as toxic materials such as herbicides, automotive oils, etc. into water bodies. As a result, lakes often respond with shallower water clarities and elevated algal abundance (greenness) during these periods as evidence by historical monitoring through the **NH LLMP**. Similarly, short-term storm events can have a profound effect on the water quality. Take for instance the "100 year storm" (October 21-22, 1996) that blanketed southern New Hampshire with approximately 6 inches of rain over a 30-hour period. This storm resulted in increased sedimentation and organic matter loading into our lakes as materials were flushed into the water bodies from the adjacent uplands. More recently, an August 11, 2008 precipitation event (1.91") included turbidity (particulate debris) and total phosphorus (nutrient) concentrations that were elevated nearly two orders of magnitude (100x) above baseline concentrations in Newfound Lake tributary inlets. While events such as the October 1996 and the August 2008 storms are short lived, they can have a profound effect on our water quality in the weeks to months that follow, particularly when nutrients that stimulate plant growth are retained in the lake.

NH LLMP data collected during dry years such as 1985 and 2001, on the other hand, have coincided with improved water quality for many New Hampshire lakes. Reduced pollutant transport into the lake often results in higher water quality measured as deeper water transparencies, lower microscopic plant "algae" concentrations and lower nutrient concentrations. Do all lakes experience poorer water quality as a result of heavy precipitation events? Simply stated, the answer is no. While most New Hampshire lakes are characterized by reduced water clarities, increased nutrients and elevated plant "algal" concentrations following periods, or years, of heavy precipitation, a handful of lakes actually benefit from these types of events. The water bodies that improve during wet periods are generally lakes characterized by high nutrient concentrations and high "algal" concentrations that are diluted by watershed runoff and thus benefit during periods, or years, of heavy rainfall. However, these more nutrient enriched lakes remain susceptible to nutrients entering the lake from seepage sources such as poorly functioning septic systems.

Precipitation (2009)

The 2009 annual precipitation (reported as "rainfall" water equivalent) measured 52.28 inches and was significantly higher than the 31 year, 1979-2009, average of 43.38 inches (note: precipitation data are reported for the Lakeport 2 Climatological sampling station located in Laconia New Hampshire: 43°33'N and 71°28'W). 2009 began with near to below average monthly rainfall through the month of May (Figure 5). However, the precipitation pattern abruptly shifted to above average rainfall during the months of June and July during which the monthly rainfall totals were over three inches above average. Above average monthly precipitation was also documented in August followed by nearly two inches below average rainfall in September and 2 inches above average rainfall in October. The year closed out with near to above average rainfall during the months of November and December, respectively.

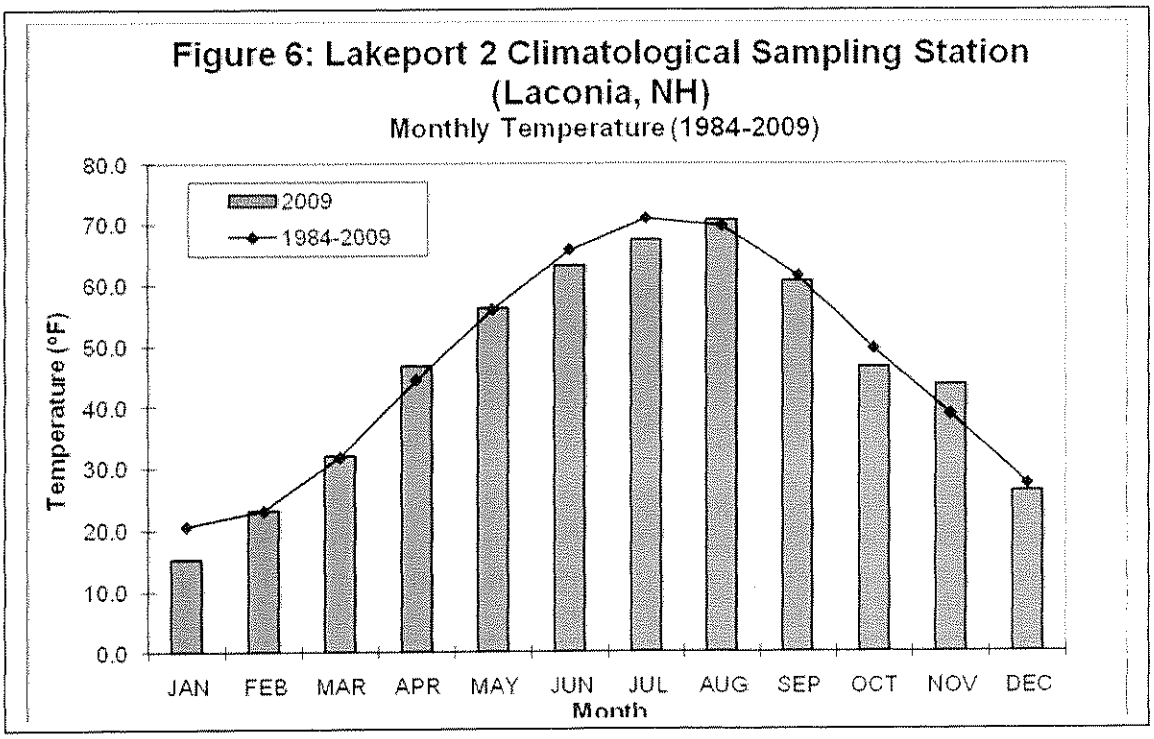


Temperature (2009)

Similar to the impact of precipitation extremes, temperature extremes can have far reaching effects on the water quality, particularly early in the year and during the summer months. Atypically cold winter periods can promote the accumulation of snowpack while atypically warm periods can account for a rapid snowpack melt resulting in flooding and a massive influx of materials (e.g. nutrients, sediments) into our lakes during the late winter and early spring months. Early spring runoff periods coincide with minimal vegetative cover (that acts as a pollutant filter and soil stabilizer) and thus leaves the landscape highly susceptible to erosion. As we progress into the summer months, atypically warm periods can enhance both microscopic "algal" and macroscopic aquatic "weed" plant growth. During the summer growing season, above average temperatures often result in algal blooms that can reach nuisance proportions under optimal conditions. These nuisance blooms can include surface algal "scums" that cover the lake and wash up on the windward lakeshores.

During years such as 1994 and 1995, when above average temperatures exemplified the summer months, participating **NH LLMP** lakes were generally characterized by increased algal concentrations, particularly in the shallows, where filamentous cotton-candy-like clouds of algae (i.e. *Mougeotia*) flourished. Other **NH LLMP** lakes had increased algal growth (greenness) and shallower water transparencies during these "hot" periods.

The January 2009 average monthly temperature was over five degrees cooler than the twenty-six year (1984-2009) monthly average while the average February and March temperatures were near normal (Figure 6). The accumulation of snowpack during the winter months of January, February and March (Figures 6 & 7) translated into the potential for an intense period of spring runoff as temperatures rose in April and May.



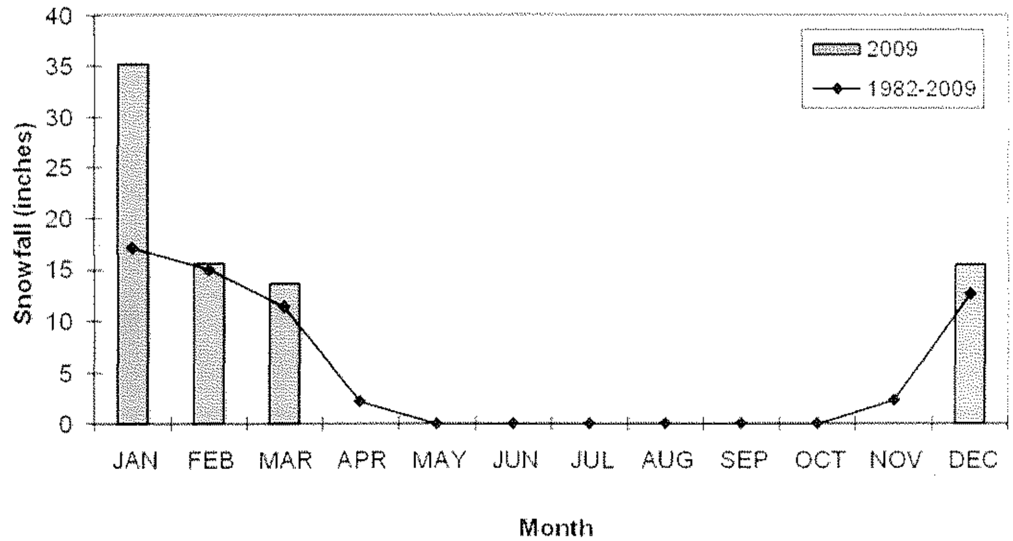


Figure 7: Lakeport 2 Climatological Sampling Station (Laconia, NH)
Monthly Snowfall (1982-2009)

Water Quality Impacts Are Related to Weather and Human Activities

Water Transparency and Dissolved "tea" Colored Water

As previously mentioned, shallower water transparency readings are characteristic of most New Hampshire lakes during wet years and following short term precipitation events. Wet periods often coincide with greater concentrations of dissolved "tea" colored compounds (dissolved organic matter resulting from the breakdown of vegetation and soils) washed in from surrounding forests and wetlands. Dissolved water color is not indicative of water quality problems (although large increases in dissolved color sometimes follow large land clearing operations) but in some of our more pristine program lakes, it nevertheless has a large effect on water clarity changes. Data collected by the **Center for Freshwater Biology (CFB)** since 1985 indicate most lakes are characterized by higher dissolved "tea" colored water during wet years relative to years more typical in terms of annual precipitation levels. In some of our more highly "tea" colored lakes the early spring months are also characterized by higher dissolved color concentrations, relative to mid-summer levels, due to the heavy runoff periods that flush highly colored water into our lakes during the period of spring snowmelt and following heavy spring rains.

Sediment Loading

Sediments are continuously flushed into our lakes and ponds during periods of heavy watershed runoff, particularly during snowmelt and again during and following sporadic storm events during the summer and fall months. Many New Hampshire lakes experience water clarity decreases following storm events such as those described above. Lakes, ponds and rivers are particularly susceptible to sediment loadings in the early spring months when vegetated shoreline buffers, often referred to as riparian buffers, are reduced. With limited vegetation to trap sediments and suspended materials, a high percentage of the particulate debris and dissolved materials are flushed into the lake. Human activities such as logging, agriculture, construction and land clearing can also increase sediment displacement during and following heavy storm events throughout the year. As sediment is transported into surface waters it can degrade water quality in a number of ways. When fine sediments (silt) enter a lake they tend to remain in the water column for relatively long periods of time. These suspended sediments can be abrasive to fish gills, ultimately leading to fish kills. Suspended sediments also reduce the available light necessary for plant growth that can result in plant die-offs and the subsequent oxygen depletion under extreme conditions.

As sediments settle out of the water column they can smother bottom dwelling aquatic organisms and fish spawning habitat. As the dead materials begin to decay the result can be noxious odors as well as stimulation of nuisance plant growth (i.e. scums along the lake-bottom; new macroscopic plant growth). Note: one should keep in mind that nuisance plants such as water milfoil (*Myriophyllum heterophyllum*) will generally regenerate more rapidly than more favorable plant forms. This can result in more problematic weed beds than those present before the disturbance. Habitat changes associated with the accumulation of fine sediments and associated "muck" might also favor increased nuisance plant growth in the future. Another unfavorable attribute of sediment loading is that the sediments tend to carry with them other forms of contaminants such as pathogens, nutrients and toxic chemicals (i.e. herbicides and pesticides).

Early symptoms of excessive sediment runoff include deposits of fine material along the lake-bottom, particularly in close proximity to tributary inlets and disturbed regions previously discussed (i.e. construction sites, logging sites, etc.). Silt may be visible covering rocks or aquatic vegetation along the lake-bottom. During periods of heavy overland runoff the water might appear brown and turbid which reflects the sediment load. As material collects along the lake-bottom you might notice a change in the weed composition reflecting a change in the substrate type (note: aquatic plants will display natural changes in abundance and distribution, so be careful not to jump to hasty conclusions). If excessive sediment loading is suspected, take a closer look in these areas and assess whether or not the change is associated with sediment loading (look for the warning signs discussed above) or whether the changes might be attributable to other factors.

Nutrient Loading

Nutrient loading is often greatest during heavy precipitation events, particularly during the periods of heavy watershed runoff. Phosphorus is generally considered the limiting nutrient for excessive plant and algal growth in New Hampshire lakes. Elevated phosphorus concentrations are generally most visible when documented in our tributary inlets where nutrients are concentrated in a relatively small volume of water. Much of the phosphorus entering our lakes is attached to particulate matter (i.e. sediments, vegetative debris), but may also include dissolved phosphorus associated with fertilizer applications and septic system discharge.

Microscopic "Algal" and Macroscopic "Weed" Plant Growth

Historical **Lakes Lay Monitoring Program** data indicate most lakes experience "algal blooms" during years with above average summer temperatures (June, July and August) while years with heavy precipitation are also associated with an increased frequency and occurrence of "algal blooms". "Algal blooms" are often green water events associated with decreases in water clarity due to their ability to absorb and scatter light within the water column, but can also accumulate near the lake bottom in shallow areas as "mats" or on the water surface as "scums" and "clouds". During some years, such as 1996, the "algal blooms" are predominantly green water events composed of algae distributed within the water column. New Hampshire lakes were particularly susceptible to algal blooms in 1996 as a function of the heavy runoff associated with an atypically wet year. Wet years such as 1996 can be particularly hard on lakes where excessive fertilizer applications, agricultural practices and construction activities favor the displacement of nutrients into surface waters. The occasional formation of certain algal blooms is a naturally occurring phenomenon and is not necessarily associated with changes in lake productivity. However, increases in the occurrence of bloom conditions can be a sign of eutrophication (the "greening" of a lake). Shifts from benign (clean water) forms to nuisance (polluted water) cyanobacterial forms such as *Anabaena*, *Aphanizomenon* and *Oscillatoria*, can also be a warning sign that improper land use practices are contributing excessive nutrients into the lake.

Filamentous cotton-candy-like "clouds" of the nuisance green algae, *Mougeotia* and related species, have been well documented in 1994 and 1995 when the temperatures during the months of June and July were well above normal. These algal "clouds" often develop within nearshore weed beds where they can be seen along the lake-bottom and tend to flourish during warm periods. During cooler years, this type of algal growth is kept "in check" and generally does not reach nuisance proportions. In other lakes, metalimnetic algae, algae which tend to grow in a thin layer along the thermocline gradient in a lake's middle depths, sometimes migrate up towards the lake surface causing a "bloom" event. If these algae are predominantly "nuisance" forms, like certain green or blue-green algae, they can be an early indication of nutrient loading.

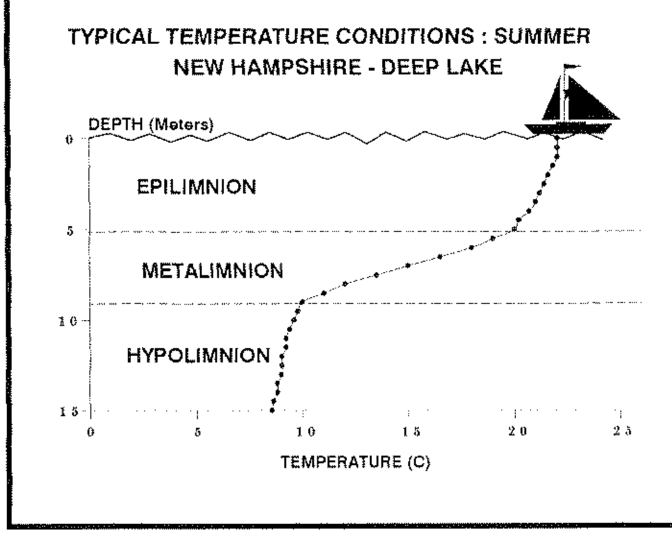
DISCUSSION OF LAKE AND STREAM MONITORING MEASUREMENTS

The section below details the important concepts involved for the various testing procedures used in the **New Hampshire Lakes Lay Monitoring Program**. Certain tests or sampling performed at the time of the optional **Center for Freshwater Biology** field trip are indicated by an asterisk (*).

Thermal Stratification in the Deep Water Sites

Lakes in New Hampshire display distinct patterns of temperature stratification, that develop as the summer months progress, where a layer of warmer water (the **epilimnion**) overlies a deeper layer of cold water (**hypolimnion**). The layer that separates the two regions characterized by a sharp drop in temperature with depth is called the **thermocline** or **metalimnion** (Figure 8). Some shallow lakes may be continually mixed by wind action and will never stratify. Other lakes may only contain a developed epilimnion and metalimnion.

Figure 8



Water Transparency

Secchi Disk depth is a measure of the water transparency. The deeper the depth of Secchi Disk disappearance, the more transparent the lake water; light penetrates deeper if there is little dissolved and/or particulate matter (which includes both living and non-living particles) to absorb and scatter it.

In the shallow areas of many lakes, the Secchi Disk will hit bottom before it is able to disappear from view (what is referred to as a "Bottom Out" condition). Thus, Secchi Disk measurements are generally taken over the deepest sites of a lake. Transparency values greater than 4 meters are typical of clear, unproductive lakes while transparency values less than 2.5 meters are generally an indication of highly productive lakes. Water transparency values between 2.5 meters and 4 meters are generally considered indicative of moderately productive lakes.

Chlorophyll *a*

The chlorophyll *a* concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic states. **Eutrophic** lakes are highly productive with large concentrations of algae and aquatic plants due to nutrient enrichment. Characteristics include accumulated organic matter in the lake basin and lower dissolved oxygen in the bottom waters. Summer chlorophyll *a* concentrations average above 7 mg m^3 (7 milligrams per cubic meter; 7 parts per billion). **Oligotrophic** lakes have low productivity and low nutrient levels and average summer chlorophyll *a* concentrations that are generally less than 3 mg m^3. These lakes generally have cleaner bottoms and high dissolved oxygen levels throughout. **Mesotrophic** lakes are intermediate in productivity with concentrations of chlorophyll *a* generally between 3 mg m^3 and 7 mg m^3. Testing is sometimes done to check for **metalimnetic algal populations**, algae that layer out at the thermocline and generally go undetected if only epilimnetic (point or integrated) sampling is undertaken. Chlorophyll concentrations of a water sample collected in the thermocline is compared to the integrated epilimnetic sample. Greater chlorophyll levels of the point sample, in conjunction with microscopic examination of the samples (see Phytoplankton section below), confirm the presence of such a population of algae. These populations should be monitored as they may be an early indication of increased nutrient loading into the lake.

Turbidity *

Turbidity is a measure of suspended material in the water column such as sediments and planktonic organisms. The greater the turbidity of a given water body the lower the Secchi Disk transparency and the greater the amount of particulate matter present. Turbidity is measured as nephelometric turbidity units (NTU), a standardized method among researchers. Turbidity levels are generally low in New Hampshire reflecting the pristine condition of the majority of our lakes and ponds. Increasing turbidity values can be an indication of increasing lake productivity or can reflect improper land use practices within the watershed which destabilize the surrounding landscape and allow sediment runoff into the lake.

While Secchi Disk measurements will integrate the clarity of the water column from the surface waters down to the depth of disappearance, turbidity measurements are collected at discrete depths from the surface down to the lake bottom. Such discrete sampling can identify layering algal populations (previously discussed) that are undetectable when measuring Secchi Disk transparency alone.

Dissolved Color

The dissolved color of lakes is generally due to dissolved organic matter from **humic substances**, which are naturally-occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances generally do not threaten water quality except as they diminish sunlight penetration into deep waters. Increases in dissolved watercolor can be an indication of increased development within the watershed as many land clearing activities (construction, deforestation, and the resulting increased run-off) add additional organic material to lakes. Natural fluctuations of dissolved color occur when storm events increase drainage from wetlands areas within the watershed. As suspended sediment is a difficult and expensive test to undertake, both dissolved color and chlorophyll information are important when interpreting the Secchi Disk transparency

Dissolved color is measured on a comparative scale that uses standard chloroplatinate dyes and is designated as a color unit or ptu. Lakes with color below 10 ptu are very clear, 10 to 20 ptu are slightly colored, 20 to 40 ptu are lightly tea colored, 40 to 80 ptu are tea colored and greater than 80 ptu indicates highly colored waters. Generally the majority of New Hampshire lakes have color between 20 to 30 ptu.

Total Phosphorus

Of the two "nutrients" most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources arise primarily through human related activity in a watershed. Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and thus it is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton. As little as 10 parts per billion of phosphorus in a lake can cause an algal bloom.

Generally, in the more pristine lakes, phosphorus values are higher after spring melt when the lake receives the majority of runoff from its surrounding watershed. The nutrient is used by the algae and plants which in turn die and sink to the lake bottom causing surface water phosphorus concentrations to decrease as the summer progresses. Lakes with nutrient loading from human activities and sources (agriculture, logging, sediment erosion, septic systems, etc.) will show greater concentrations of nutrients as the summer progresses or after major storm events.

Soluble Reactive Phosphorus *

Soluble reactive phosphorus is a fraction of the (total) phosphorus that consists largely of orthophosphate, the form of phosphorus that is directly taken up by algae and that stimulates growth. Soluble reactive phosphorus is obtained by filtering a water sample through a fine mesh filter, generally a 0.45 micron membrane filter, which effectively removes the particulate matter from the sample. Soluble reactive phosphorus concentrations are thus less than, or equal to, the measured total phosphorus concentrations for a water sample.

Soluble reactive phosphorus typically occurs in trace concentrations while applications of fertilizers as well as septic system effluent can be associated with elevated concentrations. Knowledge of both the total phosphorus and the soluble reactive phosphorus is important to understanding the sources of phosphorus into a lake and to understanding the lake's response to the phosphorus loading. For instance, a lake experiencing soluble reactive phosphorus runoff from a fertilized field may exhibit immediate water quality decline (i.e. increased algal growth) while lakes experiencing elevated total phosphorus concentrations associated with sediment washout may not exhibit clear symptoms of increased nutrient loading for years.

Streamflow

Streamflow, when collected in conjunction with stream channel information, is a measure of the volume of water traversing a given stream stretch over a period of time and is often expressed as cubic meters per second. Knowledge of the streamflow is important when determining the amount of nutrients and other pollutants that enter a lake. Knowledge of the streamflow in conjunction with nutrient concentrations, for instance, will provide the information necessary to calculate phosphorus loading values and will in turn be useful in discerning the more impacted areas within a watershed.

pH *

The pH is a way of expressing the acidic level of lake water, and is generally measured with an electrical probe sensitive to hydrogen ion activity. The pH scale has a range of 1 (very acidic) to 14 (very "basic" or alkaline) and is logarithmic (i.e.: changes in 1 pH unit reflect a ten times difference in hydrogen ion concentration). Most aquatic organisms tolerate a limited range of pH and most fish species require a pH of 5.5 or higher for successful growth and reproduction.

Alkalinity

Alkalinity is a measure of the buffering capacity of the lake water. The higher the alkalinity value, the more acid that can be neutralized. Typically lakes in New Hampshire have low alkalinities due to the absence of carbonates and other natural buffering minerals in the bedrock and soils of lake watersheds.

Decreasing alkalinity over a period of a few years can have serious effects on the lake ecosystem. In a study on an experimental acidified lake in Canada by Schindler, gradual lowering of the pH from 6.8 to 5.0 in an 8-year period resulted in the disappearance of some aquatic species, an increase in nuisance species of algae and a decline in the condition and reproduction rate of fish. During the first year of Schindler's study the pH remained unchanged while the alkalinity declined to 20 percent of the pretreatment value. The decline in alkalinity was sufficient to trigger the disappearance of zooplankton species, which in turn caused a decline in the "condition" of fish species that fed on the zooplankton.

The analysis of alkalinity employed by the **Center for Freshwater Biology** includes use of a dilute titrant allowing an order of magnitude greater sensitivity and precision than the standard method. Two endpoints are recorded during each analysis. The first endpoint (gray color of dye; pH endpoint of 5.1) approximates low level alkalinity values, while the second endpoint (pink dye color; pH endpoint of 4.6) approximates the alkalinity values recorded historically, such as NH Fish and Game data, with the methyl-orange endpoint method.

The average alkalinity of lakes throughout New Hampshire is low, approximately 6.5 mg per liter (calcium carbonate alkalinity). When alkalinity falls below 2 mg per liter the pH of waters can greatly fluctuate. Alkalinity levels are most critical in the spring when acid loadings from snowmelt and run-off are high, and many aquatic species are in their early, and most susceptible, stages of their life cycle.

Specific Conductivity *

The specific conductance of a water sample indicates concentrations of dissolved salts. Leaking septic systems and deicing salt runoff from highways can cause high conductivity values. Fertilizers and other pollutants can also increase the conductivity of the water. Conductivity is measured in **micromhos** (the opposite of the measurement of resistance **ohms**) per centimeter, more commonly referred to as micro-Siemans (υS). Specific conductivity implies the measurements are standardizes to the equivalent room temperature reading as conductivity will increase with increasing temperature.

Sodium and Chloride *

Low levels of sodium and chloride are found naturally in some freshwater and groundwater systems while high sodium and chloride concentrations are characteristic of the open ocean and are elevated in estuarine systems as well. Elevated sodium and chloride concentrations in freshwater or groundwater systems, that exceed the natural baseline concentrations, are commonly associated with the application of road salt. Sodium and particularly chloride are highly mobile and, relatively speaking, move into the surface and groundwater relatively unimpeded. Sodium and chloride concentrations can become elevated during periods of heavy snow pack melt when the salts are flushed into surface waters and have also been observed in elevated concentrations during the summer months when low flow conditions concentrate the sodium and chloride.

Road salt runoff is known to adversely impact roadside vegetation as is oftentimes evidenced by bleached (discolored) leaves and needles and in more extreme instances dead trees and shrubs. The United States Environmental Protection Agency (EPA) has set the standard for protection of aquatic life, both plants and animals, at 230 milligrams per liter (mg/l). The EPA has also established a secondary maximum contaminant level of 250 mg/l for both sodium and chloride, predominantly for taste, while the sodium advisory limit for persons with hypertention is 20 mg/l

Dissolved Oxygen and Free Carbon Dioxide *

Oxygen is an essential component for the survival of aquatic life. Submergent plants and algae take in carbon dioxide and create oxygen through **photosynthesis** by day. **Respiration** by both animals and plants uses up oxygen continually and creates **carbon dioxide**. Dissolved oxygen profiles determine the extent of declining oxygen concentrations in the lower waters. High carbon dioxide values are indicative of low oxygen conditions and accumulating organic matter. For both gases, as the temperature of the water decreases, more gas can be dissolved in the water.

The typical pattern of clear, unproductive lakes is a slight decline in hypolimnetic oxygen as the summer progresses. Oxygen in the lower waters is important for maintaining a fit, reproducing, cold water fishery. Trout and salmon generally require oxygen concentrations above 5 mg per liter (parts per million) in the cool deep waters. On the other hand, carp and catfish can survive very low oxygen conditions. Oxygen above the lake bottom is important in limiting the release of nutrients from the sediments and minimizing the collection of undecomposed organic matter.

Bacteria, fungi and other **decomposers** in the bottom waters break down organic matter originating from the watershed or generated by the lake. This process uses up oxygen and produces carbon dioxide. In lakes where organic matter accumulation is high, oxygen depletion can occur. In highly stratified eutrophic lakes the entire hypolimnion can remain unoxygenated or **anaerobic** until fall mixing occurs.

The oxygen peaks occurring at surface and mid-lake depths during the day are quite common in many lakes. These characteristic **heterograde oxygen curves** are the result of the large amounts of oxygen, the by-product of photosynthesis, collecting in regions of high algal concentrations. If the peak occurs in the thermocline of the lake, metalimnetic algal populations (discussed above) may be present.

Underwater Light *

Underwater light available to photosynthetic organisms is measured with an **underwater photometer** which is much like the light meter of a camera (only waterproofed!). The **photic zone** of a lake is the volume of water capable of supporting photosynthesis. It is generally considered to be delineated by the water's surface and the depth that light is reduced to one percent surface iridescence by the absorption and scattering properties of the lake water. The one percent depth is sometimes termed the **compensation depth**. Knowledge of light penetration is important when considering lake productivity and in studies of submerged vegetation. Discontinuity (abrupt changes in the slope) of the profiles could be due to metalimnetic layering of algae or other particulates (discussed above). The underwater photometer allows the investigator to measure light at depths below the Secchi Disk depth to supplement the water clarity information.

Indicator Bacteria *

Certain disease causing organisms, pathogenic bacteria, viruses and parasites, can be spread through contact with polluted waters. Faulty septic systems, sewer leaks, combined sewer overflows and the illegal dumping of wastes from boats can contribute fecal material containing these pathogens. Typical water testing for pathogens involves the use of detecting coliform bacteria. These bacteria are not usually considered harmful themselves but they are relatively easy to detect and can be screened for quickly. Thus, they make good surrogates for the more difficult to detect pathogens.

Total coliform includes all coliform bacteria that arise from the gut of animals or from vegetative materials. **Fecal coliform** are those specific organisms that inhabit the gut of warm blooded animals. Another indicator organism **Fecal streptococcus** (sometimes referred to as **enterococcus**) also can be monitored. The ratio of fecal coliform to fecal strep may be useful in suggesting the type of animal source responsible for the contamination. In 1991, the State of New Hampshire changed the indicator organism of preference to *E. coli* which is a specific type of fecal coliform bacteria thought to be a better indicator of human contamination. The new state standard requires Class A "bathing waters" to be under 88 organisms (referred to as colony forming units; cfu) per 100 milliliters of lakewater.

Ducks and geese are often a common cause of high coliform concentrations at specific lake sites. While waterfowl are important components to the natural and aesthetic qualities of lakes that we all enjoy, it is poor management practice to encourage these birds by feeding them. The lake and surrounding area provides enough healthy and natural food for the birds and feeding them stale bread or crackers does nothing more than import additional nutrients into the lake and allows for increased plant growth. As birds also are a host to the parasite that causes "swimmers itch", waterfowl roosting areas offer a greater chance for infestation to occur. Thus while leaving offerings for our feathered friends is enticing, the results can prove to be detrimental to the lake system and to human health.

Phytoplankton *

The planktonic community includes microbial organisms that represent diverse life forms, containing photosynthetic as well as non-photosynthetic types, and including bacteria, algae, crustaceans and insect larvae (the insect larvae and zooplankton are discussed below in separate sections). Because planktonic algae or "phytoplankton" tend to undergo rapid seasonal cycles on a time scale of days and weeks, the levels of populations found should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

The composition and concentration of phytoplankton can be indicative of the trophic status of a lake. Seasonal patterns do occur and must be considered. For example **diatoms**, tend to be most abundant in April-June and October-November, in the surface or epilimnetic layers of New Hampshire lakes. As the summer progresses, the dominant types might shift to **green algae** or **golden algae**. By late season **Blue-green bacteria** generally dominate. In nutrient rich lakes, nuisance green algae and/or bluegreen bacteria might dominate continually. After fall mixing diatoms might again be found to bloom.

Zooplankton *

There are three groups of zooplankton that are generally prevalent in lakes: the **protozoa**, **rotifers** and **crustaceans**. Most research has been devoted to the last two groups although protozoa may be found in substantial amounts. Of the rotifers and the crustaceans, time and budgetary constraints usually make it necessary to sample only the larger zooplankton (macrozooplankton; larger than 80 or 150 microns; 1 million microns make up a meter). Thus, zooplankton analysis is generally restricted only to the larger crustaceans. Crustacean zooplankton are very sensitive to pollutants and are commonly used to indicate the presence of toxic substances in water. The crustaceans can be divided into two groups, the **cladocerans** (which include the "water fleas") and the **copepods**.

Macrozooplankton are an important component in the lake system. The filter feeding of the herbivorous ("grazing") species may control the population size of selected species of phytoplankton. The larger zooplankton can be an important food source for juvenile and adult planktivorous fish. All zooplankton play a part in the recycling of nutrients within the lake. Like the phytoplankton, zooplankton, tend to undergo rapid seasonal cycles. Thus, the zooplankton population density and diversity should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

Macroinvertebrates *

Macroinvertebrates generally refer to the aquatic insect community living near the bottom substrate (i.e. sediments) while other invertebrate groups such as the crayfish, leeches and the aquatic worms are also included. Like the phytoplankton and zooplankton, previously discussed, the macroinvertebrates undergo seasonal cycles and are most representative of conditions for particular periods of the year. The mayflies are probably the most well known example of a seasonal aquatic macroinvertebrate as mayfly populations metamorphosize into adults as the water temperatures increase in the spring and thus giving rise to the name "mayflies". Macroinvertebrates are also sensitive to environmental conditions such as streamflow, temperature and food availability and are most representative of particular habitats along the stream continuum (i.e. some organisms prefer slower moving stream reaches while others prefer rapidly flowing waters).

Macroinvertebrates are an essential component to a healthy aquatic habitat. Macroinvertebrates help decompose organic matter entering the system such as leaves and twigs and also serve as a food source for many fish species.

While some macroinvertebrates are capable of breathing air as we do, others have gills and utilize oxygen dissolved in the water much as fish do. Macroinvertebrates also vary in their tolerance to depleting dissolved oxygen concentrations making them a good indicator of pollutants coming into the water body. The caddis flies (Trichop-tera), the mayflies (Ephemeroptera) and the stoneflies (Plecoptera) are often considered highly sensitive to pollution while the "true" flies (Diptera) are often considered highly tolerant to pollution. However, exceptions to the above categorizations are often encountered.

A variety of indices have been proposed to characterize water bodies over a gradient of pollution levels ranging from least polluted to most polluted scenarios and often designated by assigning a numerical delineator (i.e. 1 is least polluted while 10 is most polluted). Such an index, the Hilsenhoff Biotic Index (HBI), or a modification thereof, is commonly used by stream monitoring programs around the country. Macroinvertebrate data are useful in discerning the more impacted areas within the watershed where corrective efforts should be directed. Unlike chemical measurements that represent ambient conditions in the water body, the macroinvertebrate community composition integrates the water quality conditions over a longer period (months to years) and can identify "hot" spots missed by chemical sampling. If you are interested in more information regarding macroinvertebrate monitoring contact the **LLMP** coordinator.

Fish Condition

The assessment of fish species "health" is another biological indicator of water quality. Because fish are at the top of the food chain, their condition should reflect not only water quality changes that affect them directly but also those changes that affect their food supply. The fish condition index utilized by the **New Hampshire Fish Condition Program** is based on two components; fish scale analysis and a fish condition index.

Like tree trunks, fish scales have annual growth rings (annuli) that reflect their growth history and hence, provide a long-term record of past conditions in the lake. The fish condition index, based upon length and weight measurements, is a good indicator of the fish's health at the time of collection.

The resulting fish condition data can be compared among different lakes or among different years, or the index for a particular species can be compared to standard length-to-weight relationships that have been developed by fisheries biologists for many important fish species. In the end, the "health" of the various fish species reflects the overall water quality in the respective lake or pond.

UNIVERSITY of NEW HAMPSHIRE
COOPERATIVE EXTENSION

Understanding Lake Aging (Eutrophication)

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A common concern among **New Hampshire Lakes Lay Monitoring Program (NH LLMP)** participants is a perceived increase in the density and abundance of aquatic plants in the shallows, increases in the amount of microscopic plant "algae" growth (detected as greener water), and water transparency decreases; what is known as **eutrophication**. Eutrophication is a natural process by which all lakes age and progress from clear pristine lakes to green, nutrient enriched lakes on a geological time frame of thousands of years. Much like the fertilizers applied to our lawns, nutrients that enter our lakes stimulate plant growth and culminate in greener (and in turn less clear) waters. Some lakes age at a faster rate than others due to naturally occurring attributes: watershed area relative to lake area, slope of the land surrounding the lake, soil type, mean lake depth, etc. Since our New Hampshire lakes were created during the last ice-age, which ended about 10,000 years ago, we should have a natural continuum of lakes ranging from extremely pristine to very enriched.

Classification criteria are often used to categorize lakes into what are known as **trophic states**, in other words, levels of lake plant and algae productivity or "greenness" Refer to Table 9 below for a summary of commonly used eutrophication parameters.

Table 9: Eutrophication Parameters and Categorization

Parameter	Oligotrophic "pristine"	Mesotrophic "transitional"	Eutrophic "enriched"
Chlorophyll a (*ug*/l) *	<3.0	3.0-7.0	>7.0
Water Transparency (meters) *	>4.0	2.5-4.0	<2.5
Total Phosphorus (*ug*/l) *	<15.0	15.0-25.0	>25.0
Dissolved Oxygen (saturation) #	high to moderate	moderate to low	low to zero
Macroscopic Plant (Weed) Abundance	low	moderate	high

*** Denotes classification criteria employed by Forsberg and Ryding (1980).**
 # Denotes dissolved oxygen concentrations near the lakebottom.

Oligotrophic lakes are considered "unproductive" pristine systems and are characterized by high water clarities, low nutrient concentrations, low algae concentrations, minimal levels of aquatic plant "weed" growth, and high dissolved oxygen concentrations near the lake bottom. **Eutrophic** lakes are considered "highly productive" enriched systems characterized by low water transparencies, high nutrient concentrations, high algae concentrations, large stands of aquatic plants and very low dissolved oxygen concentrations near the lake bottom. **Mesotrophic** lakes have qualities between those of oligotrophic and eutrophic lakes and are characterized by moderate water transparencies, moderate nutrient concentrations, moderate algae growth, moderate aquatic plant "weed" growth and decreasing dissolved oxygen concentrations near the lake bottom.

Is a pristine, oligotrophic, lake "better than" an enriched, eutrophic, lake? Not necessarily! As indicated above, lakes will naturally exhibit varying degrees of productivity. Some lakes will naturally be more susceptible to eutrophication than others due to their natural attributes and in turn have aged more rapidly. This is not necessarily a bad thing as our best bass fishing lakes tend to be more mesotrophic to eutrophic than oligotrophic; an ultra-oligotrophic lake (extremely pristine) will not support a very healthy cold water fishery. However, human related activities can augment the aging process (what is known as cultural eutrophication) and result in a transition from a pristine system to an enriched system in tens of years rather than the natural transitional period that should take thousands of years. Cultural eutrophication is particularly a concern for northern New England lakes where large tracts of once forested or agricultural lands are being developed, with the potential for increased sediment and nutrient loadings into our lakes, which augment the eutrophication process.

Additionally, other pollutants such as heavy metals, herbicides, insecticides and petroleum products might also affect your lake's "health". A "healthy" lake, as far as eutrophication is concerned, is one in which the various aquatic plants and animals are minimally impacted so that nutrients and other materials are processed efficiently. We can liken this process to a well-managed pasture: nutrients stimulate the growth of grasses and other plants that are eaten by grazers like cows and sheep. As long as producers and grazers are balanced, a good amount of nutrients can be processed through the system. Impact the grazers and the grass will overgrow and nuisance weeds will appear, even if nutrients remain the same. In a lake, the producers are the algae and aquatic weeds while the grazers are the microscopic animals (**zooplankton**) and aquatic insects. These organisms can be very susceptible to a wide range of pollutants at very low concentrations. If impacted, the lake can become much more productive and the fishery will be impacted as well since these same organisms are an important food source for most fish at some stage of their life.

Development upon the landscape can negatively affect water quality in a number of ways:

- <u>Removal of shore side vegetation and loss of wetlands</u> - Shore side vegetation (what is known as **riparian vegetation**) and wetlands provide a protective buffer that "traps" pollutants before reaching the lake. These buffers remove materials both chemically (through biological uptake) and physically (settling materials out). As riparian buffers are removed and wetlands lost, pollutant materials are more likely to enter the lake and in turn, favor declining water quality.

- <u>Excessive fertilizer applications</u> - Fertilizers entering the lake can stimulate aquatic plant and algal growth and in extreme cases result in noxious algal blooms. Increases in algal growth tend to diminish water transparency and under extreme cases culminate in surface "scums" that can wash up on the shoreline producing unpleasant smells as the material decomposes. Excessive nutrient concentrations also favor algal forms known to produce toxins, which irritate the skin and under extreme conditions, are dangerous when ingested.

- <u>Increased organic matter loading</u> - Organic matter (leaves, grass clippings, etc.) is a major source of nutrients in the aquatic environment. As the vegetative matter decomposes nutrients are "freed up" and can become available for aquatic plant and algal growth. In general, we are not concerned with this material entering the lake naturally (leaf senescence in the fall) but rather excessive loading of this material as occurs when residents dump or rake leaf litter and grass clippings into the lake. This material not only provides large nutrient reserves which can stimulate aquatic plant and algal growth but also makes great habitat for leaches and other potentially undesirable organisms in swimming areas.

- <u>Septic problems</u> - Faulty septic systems are a big concern as they can be a primary source of water pollution around our lakes. Septic systems are loaded with nutrients and can also be a health threat when not functioning properly.

- <u>Loss of vegetative cover and the creation of impervious surfaces</u> - A forested watershed offers the best protection against pollutant runoff. Trees and tall vegetation intercept heavy rains that can erode soils and surface materials. The roots of these plants keep the soils in place, process nutrients and absorb moisture so the soils do not wash out. Impervious surfaces (paved roads, parking lots, building roofs, etc.) reduce the water's capacity to infiltrate into the ground, and in turn, go through nature's water purification system. As water seeps into the soil, pollutants are removed from the runoff through absorption onto soil particles. Biological processes detoxify pollutants and/or immobilize substances. Surface water runoff over impervious surfaces also increases water velocities that favor the transport of a greater load of suspended and dissolved pollutants into your lake.

How can you minimize your water quality impacts?

- Minimize fertilizer applications whenever possible. Most people apply far more fertilizers than necessary, with the excess eventually draining into your lake. This not only applies to those immediately adjacent to the lake but to everybody within the watershed. Pollutants in all areas of the watershed will ultimately make their way into your lake. Have your soil tested for a nominal fee (contact your county UNH Cooperative Extension Office for further information) to find out how much fertilizer and soil amendments are really needed. Sometimes just an application of crushed lime will release enough nutrients to fit the bill. If you do use fertilizer try to use low phosphorus, slow release nitrogen varieties. And remember that under the current NH Comprehensive Shoreline Protection Act (CSPA) you cannot apply any fertilizers or amendments within 25 feet of the shore.

- Don't dump leaf litter or leaves into the lake. Compost the material or take it to a proper waste disposal center. Do not fill in wetland areas. Do not create or enhance beach areas with sand (contains phosphorus, smothers aquatic habitat, fills in lake as it gets transported away by currents and wind).
- Septic systems will not function efficiently without the proper precautionary maintenance. Have your septic system inspected every two to four years and pumped out when necessary. Since the septic system is such an expensive investment often costing around $10,000 for a complete overhaul, it is advantageous to assure proper care is taken to prolong the system's life. Additionally, following proper maintenance practices will reduce water quality degradation. Refer to:

  Pipeline: Summer 2008 Vol. 19, No. 1. Septic Systems and Source Water Protection: Homeowners can help improved community water quality.

  http://www.nesc.wvu.edu/pdf/WW/publications/pipline/PL_SU08.pdf
- Try to landscape and re-develop with consideration of how water flows on and off your property. Divert runoff from driveways, roofs and gutters to a level vegetated area or a rain garden so the water can be slowed, filtered and hopefully absorbed as recharge. Refer to:

  Landscaping at the Water's Edge: An ecological approach, 2nd edition. *$20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824.*

  Integrated Landscaping: Following Nature's Lead. $20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824
- Maintain shore side (riparian) vegetative cover when new construction is undertaken. For those who have pre-existing houses but lack vegetative buffers, consider shoreline plantings aimed at diminishing the pollution load into your lake. Refer to:

  Landscaping at the Water's Edge: An ecological approach, 2nd edition. *$20.00/ea University of New Hampshire Cooperative Extension Publications Center, Nesmith Hall, 131 Main Street, Durham NH 03824.*

  Buffers for Wetlands and Surface Waters: A Guidebook for New Hampshire Municipalities. Audubon Society of New Hampshire.

  http://www.nh.gov/oep/resourcelibrary/documents/buffershandbook.pdf
- Review the New Hampshire Comprehensive Shoreland Protection Act (CSPA) if you have shoreland property. The CSPA sets legal regulations aimed at protecting water quality. If you have any questions regarding the act or need further information contact the *Shoreline Protection Act Coordinator at* (603) 271-3503.

Lake Friendly Lawn Care

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Below is an expanded version of an article written by the author and published in the Spring 2009 "Lakeside", the newsletter of the NH Lakes Association.

The recent publication, "**Landscaping at the Water's Edge: An ecological approach, 2nd edition**" from UNH Cooperative Extension covers the importance of considering how you may landscape your shoreline property for both the improvement of water quality as well as the enhancement of your property. Lawns and lawn care, specifically for shoreline properties, are among the most popular requests for information. While the publication goes into much greater and more specific detail, the information below is a good start when considering lawns and their potential impacts to water quality.

There is often controversy and confusion regarding lawns on shoreland properties. Some consider lawns inconsistent with the natural shoreland ecology while others want to bring to their shoreland home the same look and feel as the neighborhoods in surburbia that they have grown up with. As all vegetation provides at least some water quality functions, a lawn managed in the proper way can still allow for stabilized soils, filtered water infiltration into the ground and some nutrient and pollutant capture. And as with all vegetation, lawns sequester carbon dioxide, produce oxygen and, by doing so, cool the planet. Thus, lawns still make a better alternative to pavement or patios which create greater runoff conditions and impede groundwater recharge. Of course, if managed improperly and located too close to the water, lawns and their care can add to pollutant and nutrient loading to our surface and ground waters, attract nuisance weeds and insect pests (and even big pests like Canadian Geese!), impact important plant and wildlife species, as well as greatly reduce the available potable water supply with their potential need for irrigation. So how might you maintain a lawn area to enjoy on your shoreland property (or any property for that matter) while minimizing your impacts to the water quality and natural ecology?

- **Everything in moderation** - We often hear from our health providers that moderation is the key to healthy living and the same holds true for natural systems. Questions to ask yourself here include: How much lawn or open space do we really need for our intended use? Do we need to have all of our open space as a monoculture of a single type of grass or can we live with a combination of grasses and groundcovers that match our use? There are many varieties of grasses depending on the type and frequency of use (ie: occasionally picnicking to kids playing ball everyday) and site conditions (soils, sun exposure and slope). Recently developed fescues, for example, require less maintenance (water, mowing and fertilizing) and can even be obtained with symbiotic fungi in their roots that make the grass better resistant to pests and diseases. The best approach is a mix of grass species with even some other groundcovers and white clover (or another low growing legume to naturally supply nitrogen to the soil). Talk to your county Extension educator, landscaper, or garden center expert about your options.

- **Location, location, location** - Yes, the mantra of real estate agents also works well for lawns. Additional maintenance of a lawn, even when not excessive, can still threaten water quality. To make up for this residents might consider locating the lawn as away from the shore as possible and maintaining a significant buffer area downslope from the lawn with a mix of shrubs and woody plants. A lawn right down to the water is the worst thing for the water and it will serve to attract nuisance geese. It's a known fact that keeping the vegetation high at the water's edge will discourage geese from coming onto a property. It also provides many water quality and wildlife (aquatic and near shore) related benefits.
- **Test first, apply later** - It is most important to test your soil before even thinking about applying fertilizers. Once a lawn is established, fertilizing more than once a year (unless the yearly dosage is applied in fractions) is generally excessive and can lead to excess nitrogen loading to surface and groundwater. Lawns tend to need more basic soils so sometimes even applying crushed limestone to raise the pH can release enough nutrients that were bound to the soil to maintain the lawn. A soil test will let you know exactly what you need to maintain a healthy lawn. If the test informs you that only nitrogen is needed, look for low to no phosphorus fertilizer blends (middle number of the N-P-K rating on the bag is zero) as phosphorous causes algae blooms in lakes and ponds. Generally, a well established lawn can survive adequately with no more than 1 to 2 pounds of nitrogen per 1000 square feet. The best time to apply fertilizer on an established lawn is around mid September when the grass is still active enough to incorporate the fertilizer into the plants, the summer draught is over and the surrounding vegetation is well established to capture any runoff from your lawn. Choose slow release fertilizers only, to insure less polluted runoff. Many residents apply crushed limestone in the spring and fertilize in the fall. Some residents have never felt the need to fertilize and others have had their best results just using lake water (which usually contains small amounts of N and low P) for irrigation. It is really up to you to balance the results you are looking for with the minimum applications needed. Remember the NH Comprehensive Shoreline Protection Act prohibits applying anything except limestone in areas within 25 feet of the high water line except in some circumstances like initially establishing a ground cover.
- **Read the fine print!** - A recent survey in Maine indicated that many consumers did not realize that "Weed & Feed" products contain both fertilizers and pesticides. Why pay for and put down something that can potentially threaten the health of pets, children and water quality when you may not need it in the first place? If you do have weed or insect problems consult with your county Exten-

sion educator, landscaper or garden center expert to learn of safer alternative controls. No matter what you choose always read the application directions and never over apply. Many of the plants and animals that form the foundation of the aquatic food web are extremely sensitive to pesticides so your impacts can have serious repercussions. Also be sure to apply only what you need - just because you bought a whole bag does not mean you have to apply all of it. Over-fertilization will cause more pest problems and will threaten surface and ground water supplies.

- <u>**Conserve every drop**</u> - If you are on a public water supply it is best to choose grass species with low watering requirements or use alternative irrigation supplies like rain barrels, cisterns or even the water directly from the shore. Summer water demand for lawns can be very significant in many communities. Depending on the species and soil conditions you should water, only when needed, no more than a half inch to an inch total weekly. You can use a rain gauge or a can to measure rainfall and irrigation amounts. Early morning watering is preferable to minimize evaporation loss but give the water enough time to infiltrate and to allow the leaf blades to completely dry before night so as not to encourage disease problems. Keeping the lawn height at least 3 inches or higher will also encourage deeper roots which require less water (and a mulching mower blade will allow for those grass clippings to recycle nutrients back into the soil). Remember that in times of draught and hot summer lawns are supposed to go dormant. Letting this happen is the most environmentally friendly thing you can do.

So, the choices are yours, you can have a lawn on your property with minimum impact to our waters if you can restrict its size, locate it properly, provide adequate vegetative buffer areas down-slope and use low input design and maintenance methods. To learn more about how informed landscaping can actually improve the water coming off of your property refer to "**Landscaping at the Water's Edge: An ecological approach, 2nd edition**" and/or request a presentation from your Cooperative Extension county Master Gardeners. Jeff Schloss can also be contacted to schedule a talk or workshop for your lake association.

Go with the Flow:
Understanding How Water Moves Onto, Through and Away from Your House Site

Water travels through a watershed (the catchment area) in two ways, across the land surface and down through the ground. As water traveling on the land surface moves along, following the path of least resistance, it passes across various types of land and land uses. In a state as geographically diverse as New Hampshire, a drop of water from irrigation, rain or snowmelt might travel across neighborhood roads and your driveway, through a wooded area or an open field. Unless it infiltrates down into the ground, gets intercepted by a plant or evaporates into the atmosphere, the drop will end up in a lake, pond, stream, wetland or estuary. As water travels downhill on the landscape it picks up small particles and soluble materials and carries them along to the waterbody at the end of its journey. It might pick up pesticides or fertilizers from a backyard garden or salts and oils from a driveway or patio. In times of heavy rain, fast moving waters can pick up large particles of soils and sediments and deliver large pollutant loads to our surface waters. This flow of water and materials from a given location across the land surface and into our water is called "runoff".

Controlling water runoff should be a major objective of any shoreland landscape design. As water collects and flows through channels, it gathers energy and increases its erosive force. The faster water flows, the greater the particle size and quantity of pollutants it can carry along to the receiving water body (pond, lake, stream, river, wetland or coastal water). Modifying the landscape with any type of development has the potential to degrade soil and water, resulting in changes in water flow, nutrient- and pollutant-loading, and groundwater recharge. However, if you start with a plan that takes into consideration the specific water runoff situation on your house site, your new landscape design could even improve the quality of water coming off it.

This overview will guide you through the process of assessing your current runoff situation and offer various strategies you can use to minimize the runoff from your house site. Combining these approaches with appropriate choices of plants and horticultural products is key to ensuring a healthy shoreland environment. More detail and instructions on how to map out your site assessment and design an integrated landscaping plan can be found in the UNH Cooperative Extension publication: **Landscaping at the Water's Edge: An ecological approach (2nd edition)** which can be ordered from the publications office : www.extension.unh.edu/publications.

Common Runoff Control Strategies

Infiltration - allowing water to percolate into the ground where it can be filtered by soils rather than running across the land surface where it can cause erosion and collect pollutants.

Detention - holding back or "ponding" a volume of water to slow the speed of its outflow. In some cases water detention may also allow for infiltration and evaporation to reduce the resulting outflow volume.

Diversion - preventing water from traveling over the area of concern, thereby reducing surface runoff damage and minimizing the potential for erosion and the transport of nonpoint source pollutants.

Flow Spreading - allowing a concentrated flow to spread out over a wide, gently sloping area to reduce the water velocity and encourage infiltration.

Plant absorption and transpiration - the movement of water from the shallow soil into the plant roots, up through the stems and leaves and the release of water vapor through the leaf stomates (under-leaf openings) to the atmosphere.

Typical Techniques used to control runoff

Berm – a stabilized mound of dirt or stone to create a diversion and/or redirect water flow

Check dam – A small mound of stabilized dirt or stone that breaks up the flow of water in a drainage ditch or trench to slow down velocity and allow for the settling of heavier materials.

Cut-in (or Cut-out) – A small trench that diverts water flow away from the direction of the major flow stream to prevent a significant volume of water from collecting as it runs down a driveway, walkway, or path. Multiple cut-ins may be required for long distances or high slopes.

Infiltration trench – A dug-in trench commonly used for roof runoff that allows for storage of runoff and encourages infiltration into the ground.

Plunge Pool – A dug-in hole stabilized by stone, typically placed adjacent to a drainage ditch or trench. This allows water to fall below the level of the surface to slow the runoff velocity and capture heavy particle. These are often constructed in a series along a sloped route.

Rain Garden – A shallow infiltration basin planted with water tolerant plant species, designed to capture concentrated runoff. Rain gardens are designed to pond water for just a few hours at a time, allowing it to be taken up and transpired by plants or infiltrate into the ground.

Swale – A stabilized trench that can act to store water (detention), sometimes also engineered to enhance infiltration.

Vegetated buffer – A relatively flat area stabilized with vegetation that allows water flow to spread out, slow down, infiltrate and be filtered by the soil, and/or be intercepted and transpired by plants.

Waterbar – A diversion device that diagonally crosses a sloped trail, path or road to capture and divert runoff to the side. Commonly made of a log, a stone, a small reinforced drainage channel, or a partially buried flexible material, a waterbar is most useful for small contributing areas (watersheds less than one acre) that receive light foot and vehicle traffic. Waterbars are spaced according to the slop of the land.

Following the flow

Paying attention to how water flows (or will flow) into, over and through your home site before, during and after development or landscaping, is critical in determining current and potential negative impacts. Some questions you'll want to answer before proceeding:

- What is the extent of lands and roads above the site that contribute runoff water, and where does the runoff enter your property?
- Where does the water run off impervious surfaces (paved driveways and walkways, roofs, patios, compacted soils, etc) and piped sources (sumps, gutters, etc.) go?
- Where does that water, along with the additional runoff generated in your new design, run over the site? Is it treated by vegetation and infiltrated or does it accumulate?
- Where will that water flow off your site? Does it enter the water body directly?
- Most importantly, how might you modify your design to take advantage of these factors in creating diversions, detention and infiltration areas?

Investigate the drainageways

Since water moves downhill, you need to walk your property boundary and note where the major water flows occur after a heavy rainstorm. Does the runoff from abutting roads or a neighbor's driveway flow onto your property? Are there any adjacent steeply sloped lands that rise above the level of your property? Are they extensive enough to contribute water flows during rains and snow melts? Make note of all of these off-site contributors to flow. Also note any occasional or perennial wet areas or streams at your property boundary that encroach on your site.

Investigate onsite runoff generation

Note any wet areas or seeps on your property. Now consider how your house and current landscaping features generate runoff. It is always easy to point uphill and blame runoff on other properties, but many people are surprised at how much runoff their own site creates, even in low-density development. Also note whether areas on your land divert runoff onto neighboring properties.

Take inventory of all paved and compacted areas, such as driveways, patios and walkways. Can you find evidence of water flow moving off these areas and heading downhill? You may see just a small area of sheet erosion, indicated by the appearance of worn-down gravelly areas with small stones and roots showing because finer soil particles have been washed away. Or you may see rill, visible channels where water has eroded away materials a fraction of an inch to a few inches deep. In the worst cases, you'll find gullies where water flows through channels deep enough for you to step into them.

The potential for erosion and runoff increases with site steepness, area of impervious surfaces, and size of contributing watershed area (land above your site).

Investigate the point sources of flows on your property from culverts, drain pipes, and hoses, as well as rain gutters, sump pumps, and tile drainage outlets. Culverts, drain pipes, etc. concentrate diffuse flows that need treatment and diversion to ensure they don't contribute to runoff. If the house doesn't have gutters, look for areas where the roof design intercepts and dumps rainwater onto the property. As you develop your landscape plan, consider ways you might reduce the impacts of those flows.

Account for any paths, trails and cleared areas that lead to the water. Shoreland properties almost always have pathways and cleared areas which runoff follows directly into the water body. In the worst cases, a driveway at the top of the property allows water from the road above and the gutter runoff to collect and concentrate. Runoff flowing down a pathway directly into a cleared beach area and into the water often takes a lot of sand with it.

Note how the paths follow the slope of the land. Meandering paths may function to break up runoff before it concentrates, but straight downhill paths encourage flow directly to the water. Also, note the flow-contributing areas that lie above the access area or beach. Do swaths of vegetation above help break up the flow, or does the water pretty much flow straight down and onto the area below?

Finally, look for areas where water tends to pond after it rains. Even flat areas may pond water if the soils don't drain well or if there is a lot or shallow ledge or hardpan present. Be sure to keep track of these areas and prevent additional water from reaching these locations.

Minimize and divert runoff

Significant flows coming onto your site may create runoff and erosion problems. Your design should take into account all flows that will come in contact with your newly landscaped area, as well as those flows that may cause runoff concerns in other areas on your property (or your neighbor's).

Of all the methods that can help deal with these situations, diversion and flow-spreading are the most reliable. If you can treat all of the incoming runoff by diverting it and spreading it out over a stable vegetated area before it leaves the properly, then by all means do so. However, in situations of high runoff flow coming from off-property sites such as roads, diverting some of the flow may be warranted to keep it from entering your property. The sources of offsite runoff can be diverse and you may not be able to take action without involving neighbors, road associations and municipalities, since road-drainage diversions and treatment systems require professional design and installation.

Use what you have (or can design) to break up, slow down and spread out the flow over or into a vegetated area. The goal is to prevent offsite and onsite flows from accumulating and divert them from impervious areas. You may be able to break up the flow by using shallow channels, stone check dams, small vegetated berms, or alternating areas of low and high vegetation.

Simple drainage cut-ins can break the flow and move the water from long driveways and pathways. In more challenging situations, for example, when sites are very steep or narrow you may need to hire a professional to install a waterbar or similar diversion.

If you can't divert the flows coming onto your site and can't find ways to prevent the flow from concentrating to a significant volume, then consider diverting the water into your existing vegetated areas. Or, create additional vegetated areas to allow the water to slow down, spread out and infiltrate the ground, thus losing most of its destructive force and most of its pollutant load. For this to work, you need an adequately sized vegetated area with minimal slope.

The denser the root systems of the plants in vegetated areas, the greater the volume of water the area can process. Mixed types of vegetation with different root depths will have the greatest impact, as contrasted with lawn like monocultures, which grow a single type of plant. However any type of vegetation is better than a bare, cleared, compacted, or impervious area.

The same holds true for dealing with runoff from pavement, roots, tile drainage, sump flows, and existing drainageways: capture the water and/or divert it by any means possible (plunge pools, waterbars, berms, swales and drainage trenches) to prevent it from running directly down to the shore. Conditions such as lack or space, steep slopes, and/or proximity to the shore create special challenges to diverting the water from a rain gutter or other concentrated flow. In these situations, consider alternative controls such as rain barrels, storage cisterns and infiltration trenches.

You may be able to cut down runoff generation at the source by replacing impervious areas with porous alternatives. For problematic and excessive stormwater volumes you may need to have something engineered to capture water and pump it into other areas for treatment.

If you have enough space, consider installing a rain garden, a shallow, dug-in area planted with water-tolerant plant species. Rain gardens can collect a significant volume of water during a storm, allowing the water that doesn't get used by plants to infiltrate the ground quickly and prevents it from becoming runoff. When designed and constructed correctly, the surface of a well-designed rain garden will not flood, eliminating concerns about standing water. The publication, **Landscaping at the Water's Edge**, includes resources for more information on rain garden design and appropriate plants. Or call your county Cooperative Extension office for more information.

Properly designed pathways and trails should meander across the slope and allow each segment to throw water off the trail, rather than letting it flow in a straight path, accumulating velocity and pollutants as it moves downhill. The best trails are those that follow the ridges and contours of the property. Some low vegetation planted at the corners of the meanders or staggered alternately on the sides of steeper pathways will help break up, capture, and slow down the flow of water as it moves downhill.

To maximize water quality protection as you consider the ways you want to use and enjoy your waterfront property, the key is to remove as little vegetation as possible. For all lake shores and large rivers, the state's Comprehensive Shoreland Protection Act requires that in the "waterfront buffer" (0-50 feet from shore) natural ground cover and duff (forest litter) shall remain intact. No cutting or removal of vegetation under 3 feet in height (excluding lawns) is allowed. Stumps, roots and rocks must remain intact in and on the ground. In addition, within the waterfront buffer, tree coverage is managed with a 50 foot by 50 foot grid and point system that ensures adequate forest cover and prevents new clear cutting. Within the "natural woodland buffer" (50-150 feet from shore) there are additional protections where 25 to 50 percent of that buffer must remain undisturbed dependent on lot size. See the NH DES Comprehensive Shoreline Protection Act web site for more detailed information (http://des.nh.gov/organization/divisions/water/wetlands/cspa/index.htm).

Plan to stabilize a major portion of the shoreline area with a good mix of plants. The more protective vegetation you remove from near the shore, the more you increase the area's potential for transporting pollutants to the lake or stream. Removing taller plants also opens the shore area to receive more sunlight. Exposure to more sun heats up the water, making it less desirable for aquatic organisms and more conducive to submerged and emergent weed growth including exotic invasive species.

Where you locate your water access area is also important. Areas that don't receive significant runoff from the land above make the best locations for minimizing potential impacts. Water access areas that lie directly below a runoff flow may allow the runoff to reach the water without any reduction in impact. If you have no choice of access location, try to create a diversion of the flow away from the shoreline opening and into a more vegetated area using one or more or the approaches discussed above.

Note: State wetland laws forbid dumping sand or other materials on the shoreline to make a beach. Wetland permits are required for any beach construction. Sand beaches not naturally present are discouraged as they tend to get washed away. In locations where a small opening, with stable groundcover and perhaps a few flat stones or steps will not do, you can apply for a permit for a small perched beach located just above the shoreline. Contact the Department of Environmental Services Wetlands Bureau for more information,
(http://des.nh.gov/organization/divisions/water/wetlands/index.htm).

Structural approaches

Most structural modifications for dealing with flow and runoff require professional design and installation. However, homeowners might try one or more of these simpler approaches before calling in the pros:

- Clear existing drainage-ways of accumulated materials, including loose sediments and litter, before the snow melts and the spring rains arrive. Encourage vegetative growth in these drainageways however, as the vegetation removes sediments and pollutants from the water as it passes through.

- If possible, divert other flows into your existing drainageways (as long as they themselves don't directly flow into the water body) by some shallow channeling, the use of check dams of stone or gravel, or by using small berms.
- Break up the water flow by alternating small berms down a sloped area, diverting water off into vegetated areas before it can accumulate in significant volume.

In general, anything you can do by hand or using hand tools doesn't require a permit, as long as you stay at least 25 feet away from the shoreline. Any time you have to use a power tool, vehicle or power equipment, or your project requires significant earth-moving within the 250 foot Shoreland Protection Zone, you will probably need a state permit, and possibly one or more local permits as well.

Making a Difference

A typical small shorefront lot on a moderate slope with conventional development (house, paved driveway, vegetation cleared for lawn) can increase water runoff, phosphorus pollution and sediment erosion about 5, 7, and 18 times, respectively, compared to an undisturbed, forested lot. By re-growing out a shoreland buffer of 50 feet and infiltrating the roof runoff through trenching or a rain garden, the impacts can be reduced significantly: to only 1.5 times the runoff, 2 times the phosphorus loading and less than 3 times the sediment erosion compared to the undisturbed lot.

With the knowledge of how water flows over and currently runs off your site, you now may want to consider adding water diversions, as well as vegetated buffers and infiltration areas into your landscape design to take advantage of the water-treatment properties of vegetation. The full publication: **Landscaping at the Water's Edge** contains further information on how to maintain and establish shoreline buffers, choose the appropriate plant systems for low impact and low maintenance, and how to plant and maintain lawn areas in an environmentally-friendly way.

Adapted by Jeff Schloss, UNH Extension Professor of Biological Sciences and Cooperative Extension Water Resources Specialist from his contributed chapter in: **Landscaping at the Water's Edge: An ecological approach, 2nd edition** (www.extension.unh.edu/publication). JAS 3/15/10

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REPORT FIGURES

Figure 9. Location of the 2009 and historical Great East Lake deep and shallow sampling stations, Sites 1 Center, 2 Canal Basin and 3 Maine Mann, 1^{st} Basin (Narrows), 2^{nd} Basin and 3^{rd} Basin, Town of Wakefield New Hampshire.

Great East Lake Sampling Sites

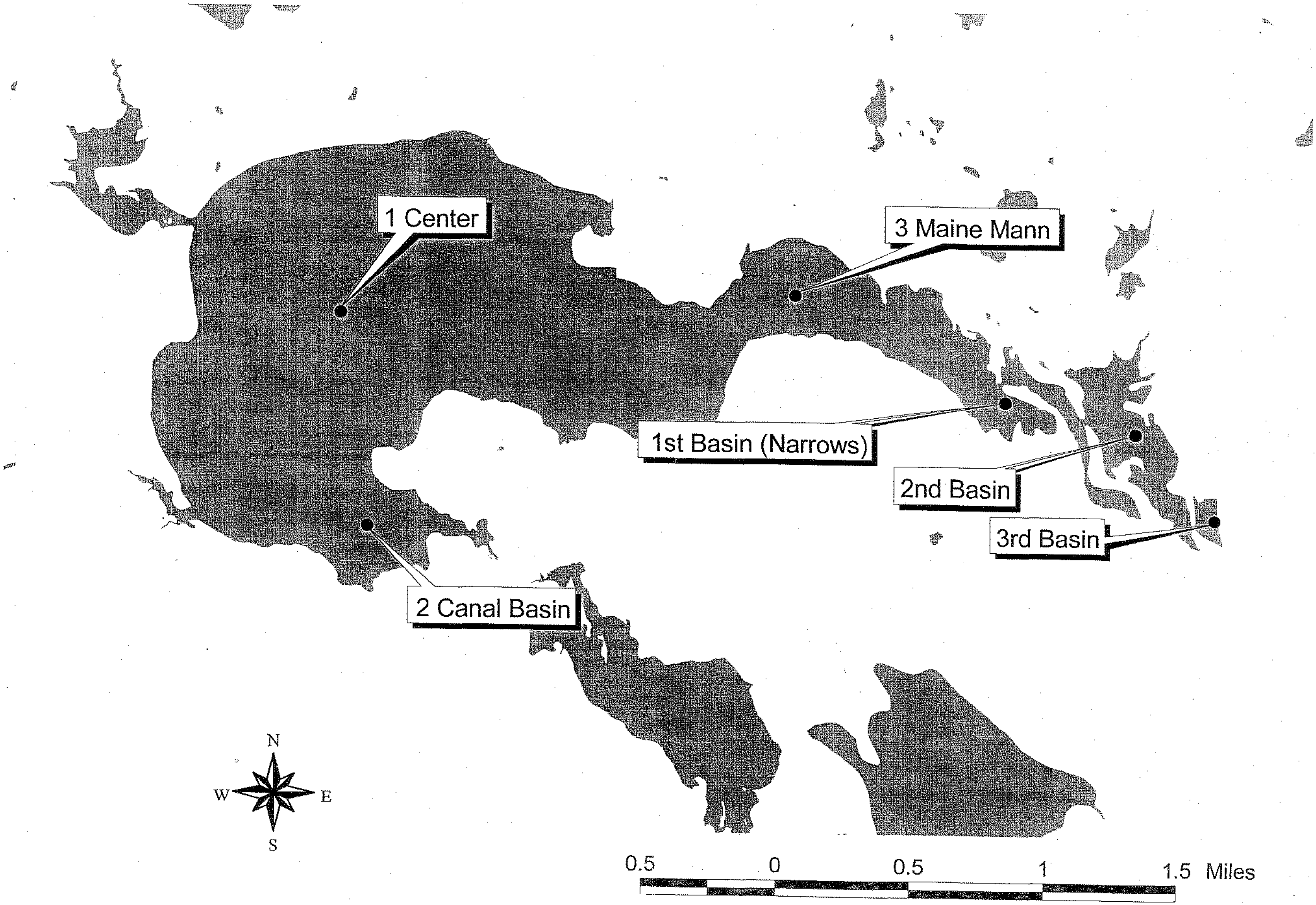
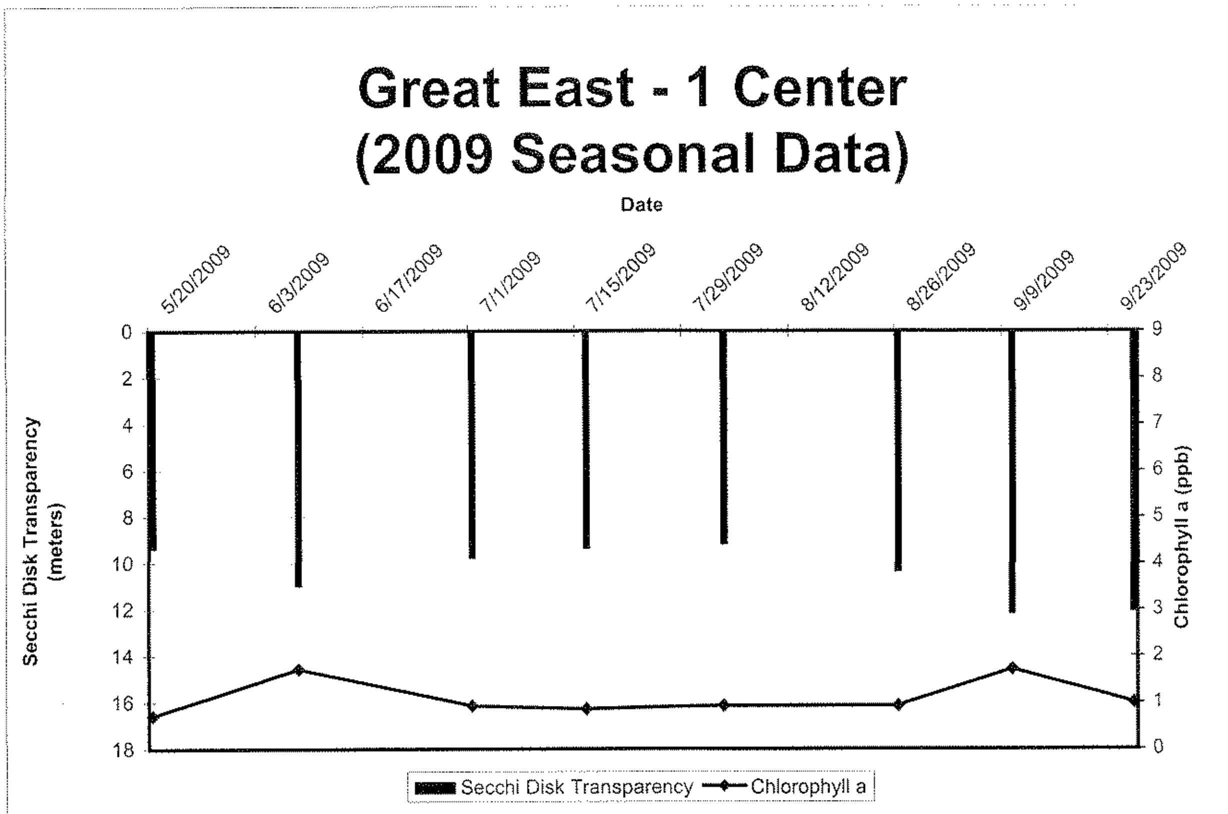


Figure 10. Great East Lake, 2009. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Site 1 Center. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

Figure 11. Great East Lake, 2009. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 1 Center. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).


Great East - 1 Center
(2009 Seasonal Data)
Date
5/20/2009
6/3/2009
6/17/2009
7/1/2009
7/15/2009
7/29/2009
8/12/2009
8/26/2009
9/9/2009
9/23/2009
Secchi Disk Transparency (meters)
0
2
4
6
8
10
12
14
16
18
Chlorophyll a (ppb)
9
8
7
6
5
4
3
2
1
0
Secchi Disk Transparency
Chlorophyll a

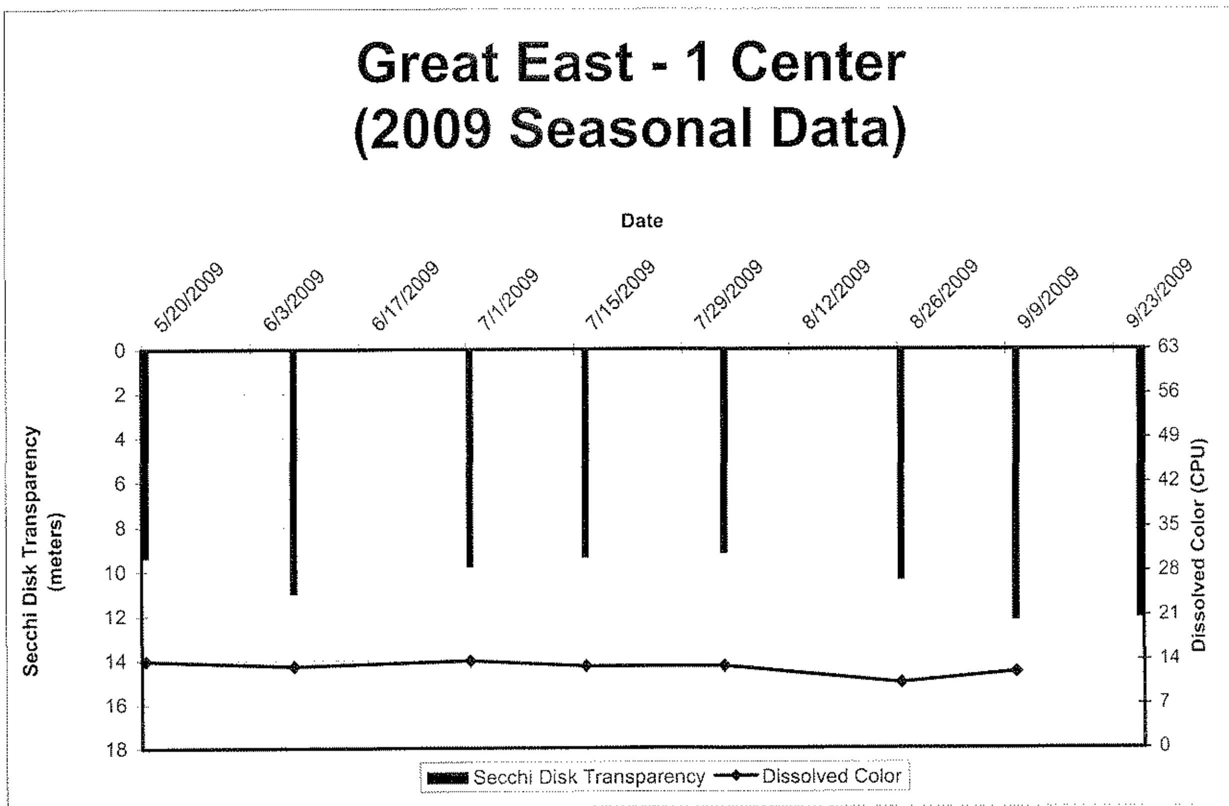
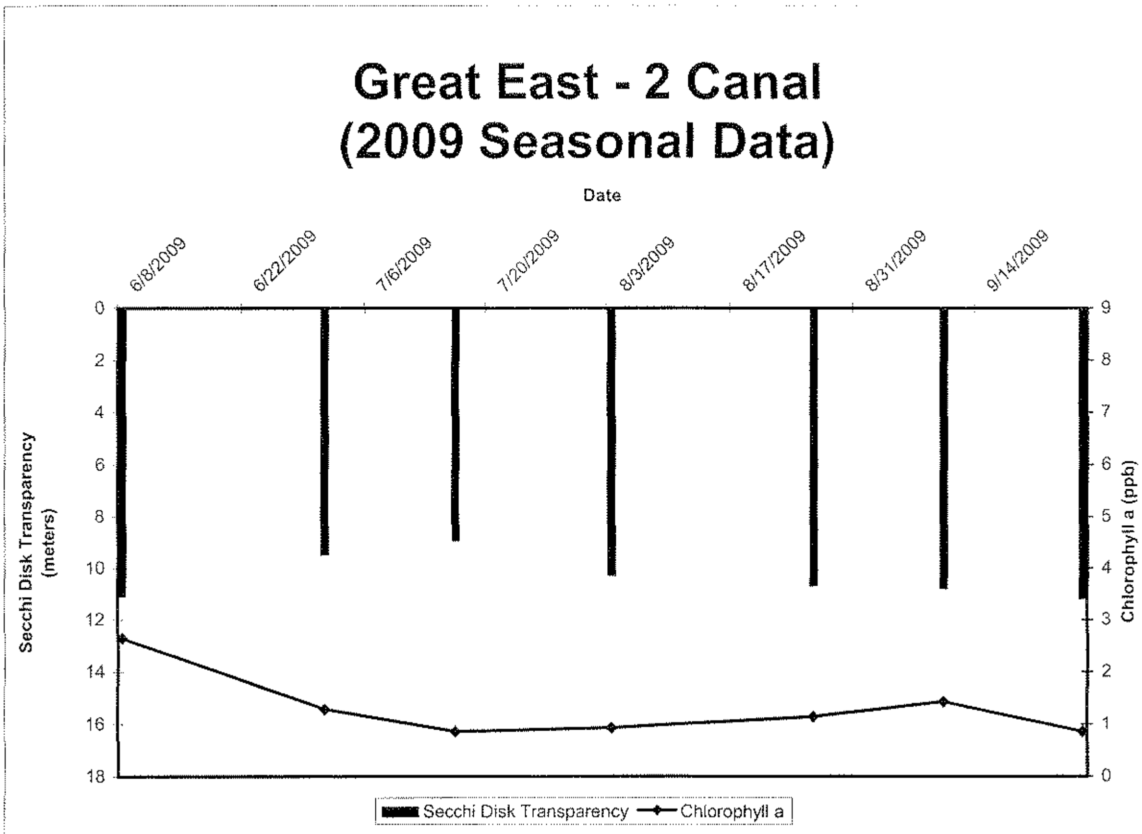

Great East - 1 Center
(2009 Seasonal Data)
Date
5/20/2009
6/3/2009
6/17/2009
7/1/2009
7/15/2009
7/29/2009
8/12/2009
8/26/2009
9/9/2009
9/23/2009
Secchi Disk Transparency (meters)
0
2
4
6
8
10
12
14
16
18
Dissolved Color (CPU)
63
56
49
42
35
28
21
14
7
0
Secchi Disk Transparency
Dissolved Color

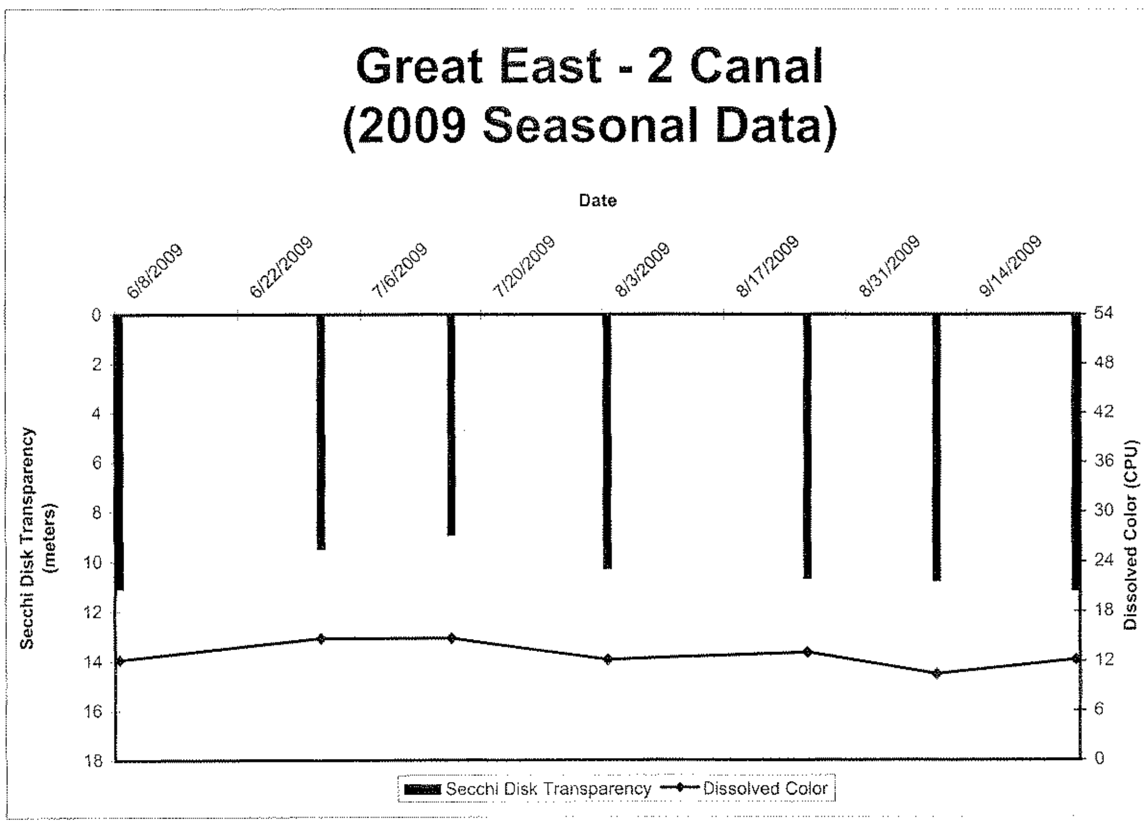
Figure 12. Great East Lake, 2009. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Site 2 Canal. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

Figure 13. Great East Lake, 2009. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 2 Canal. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).



Great East - 2 Canal
(2009 Seasonal Data)
Date
6/8/2009
6/22/2009
7/6/2009
7/20/2009
8/3/2009
8/17/2009
8/31/2009
9/14/2009
Secchi Disk Transparency (meters)
Chlorophyll a (ppb)
0
2
4
6
8
10
12
14
16
18
9
8
7
6
5
4
3
2
1
0
Secchi Disk Transparency
Chlorophyll a

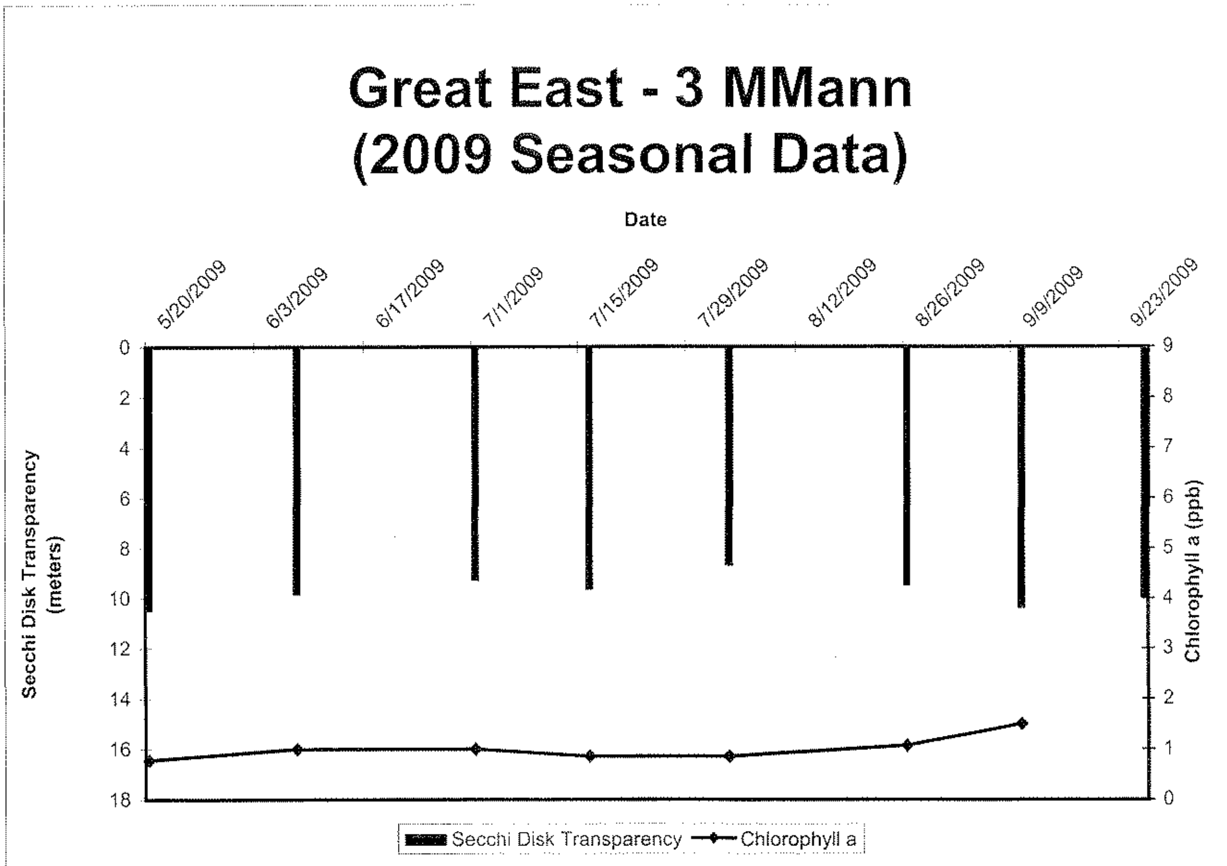


Great East - 2 Canal
(2009 Seasonal Data)
Date
6/8/2009
6/22/2009
7/6/2009
7/20/2009
8/3/2009
8/17/2009
8/31/2009
9/14/2009
Secchi Disk Transparency (meters)
Dissolved Color (CPU)
0
2
4
6
8
10
12
14
16
18
54
48
42
36
30
24
18
12
6
0
Secchi Disk Transparency
Dissolved Color

Figure 14. Great East Lake, 2009. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Site 3 MMann. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

Figure 15. Great East Lake, 2009. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 3 MMann. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).


Great East - 3 MMann
(2009 Seasonal Data)
Date
5/20/2009
6/3/2009
6/17/2009
7/1/2009
7/15/2009
7/29/2009
8/12/2009
8/26/2009
9/9/2009
9/23/2009
Secchi Disk Transparency (meters)
Chlorophyll a (ppb)
0
2
4
6
8
10
12
14
16
18
9
8
7
6
5
4
3
2
1
0
Secchi Disk Transparency
Chlorophyll a

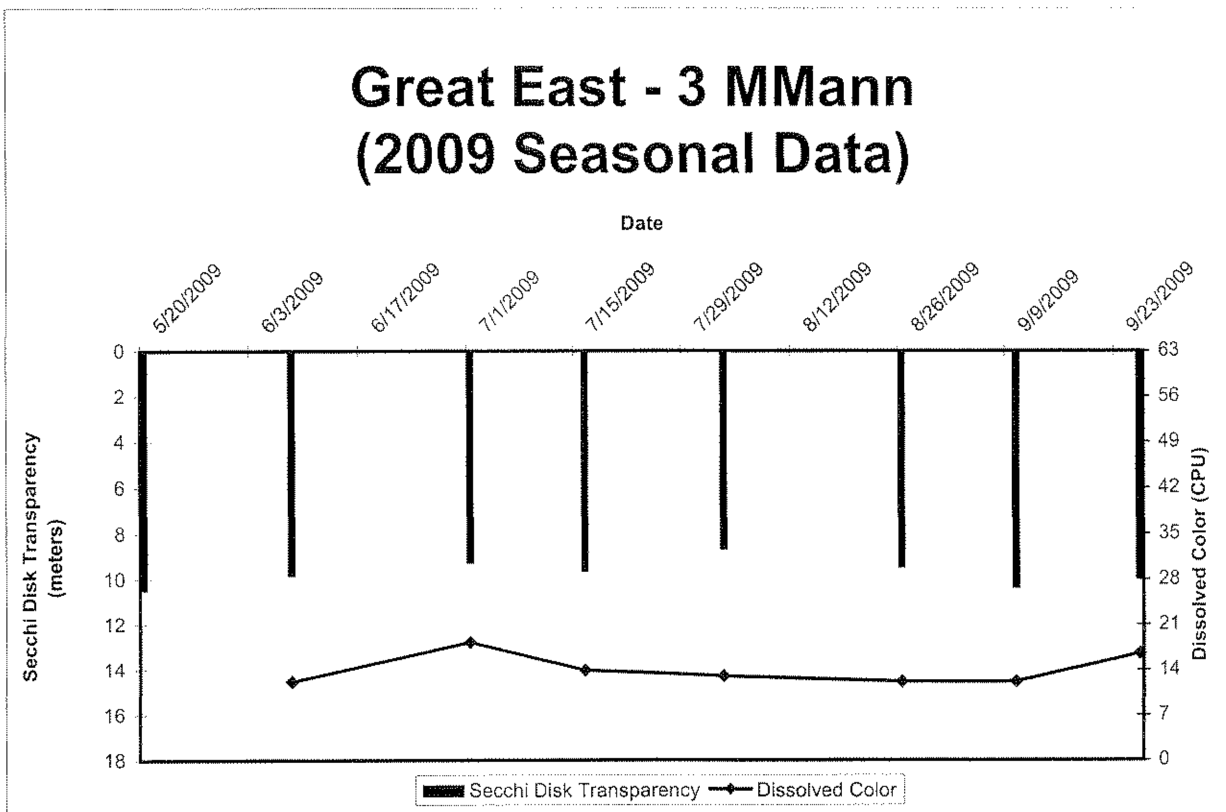
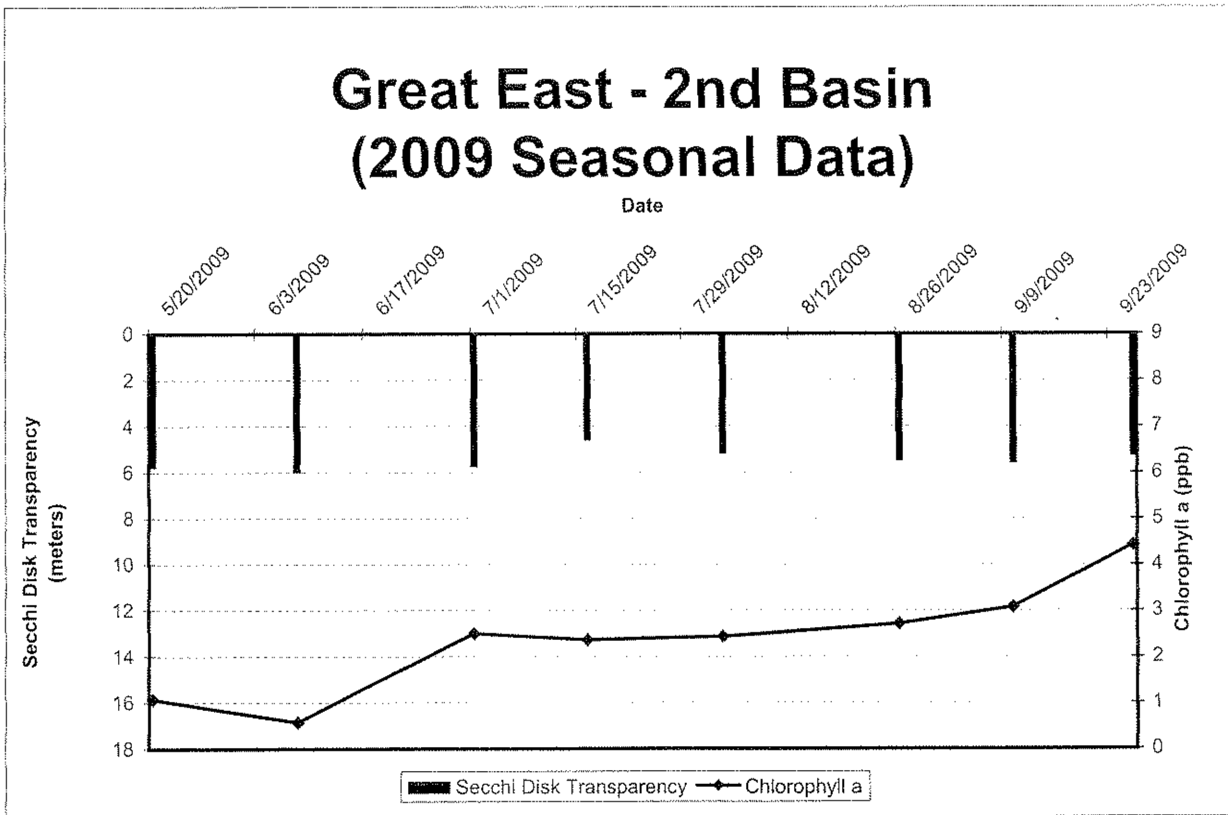

Great East - 3 MMann
(2009 Seasonal Data)
Date
5/20/2009
6/3/2009
6/17/2009
7/1/2009
7/15/2009
7/29/2009
8/12/2009
8/26/2009
9/9/2009
9/23/2009
Secchi Disk Transparency (meters)
Dissolved Color (CPU)
0
2
4
6
8
10
12
14
16
18
63
56
49
42
35
28
21
14
7
0
Secchi Disk Transparency
Dissolved Color

Figure 16. Great East Lake, 2009. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Site 2nd Basin. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

Figure 17. Great East Lake, 2009. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 2nd Basin. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).


Great East - 2nd Basin
(2009 Seasonal Data)
Date
5/20/2009
6/3/2009
6/17/2009
7/1/2009
7/15/2009
7/29/2009
8/12/2009
8/26/2009
9/9/2009
9/23/2009
Secchi Disk Transparency (meters)
Chlorophyll a (ppb)
0
2
4
6
8
10
12
14
16
18
9
8
7
6
5
4
3
2
1
0
Secchi Disk Transparency
Chlorophyll a

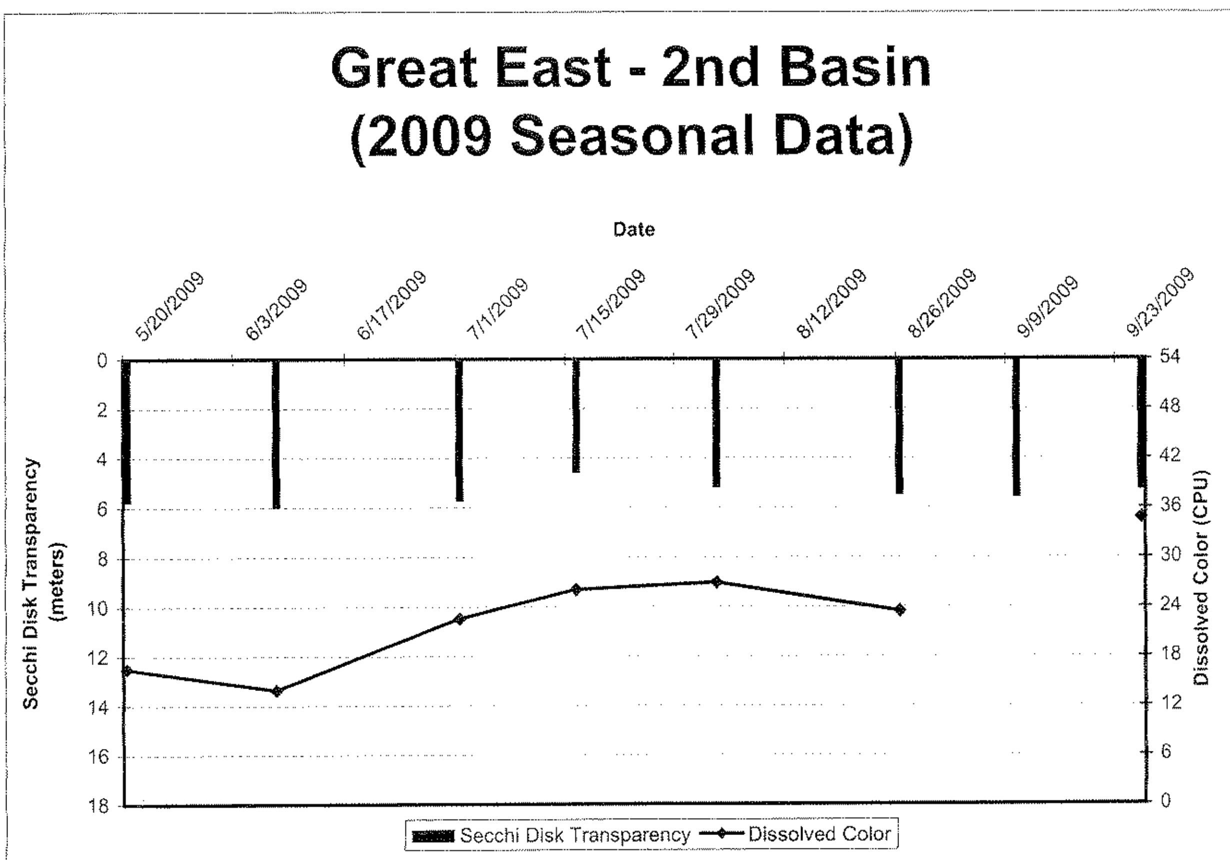
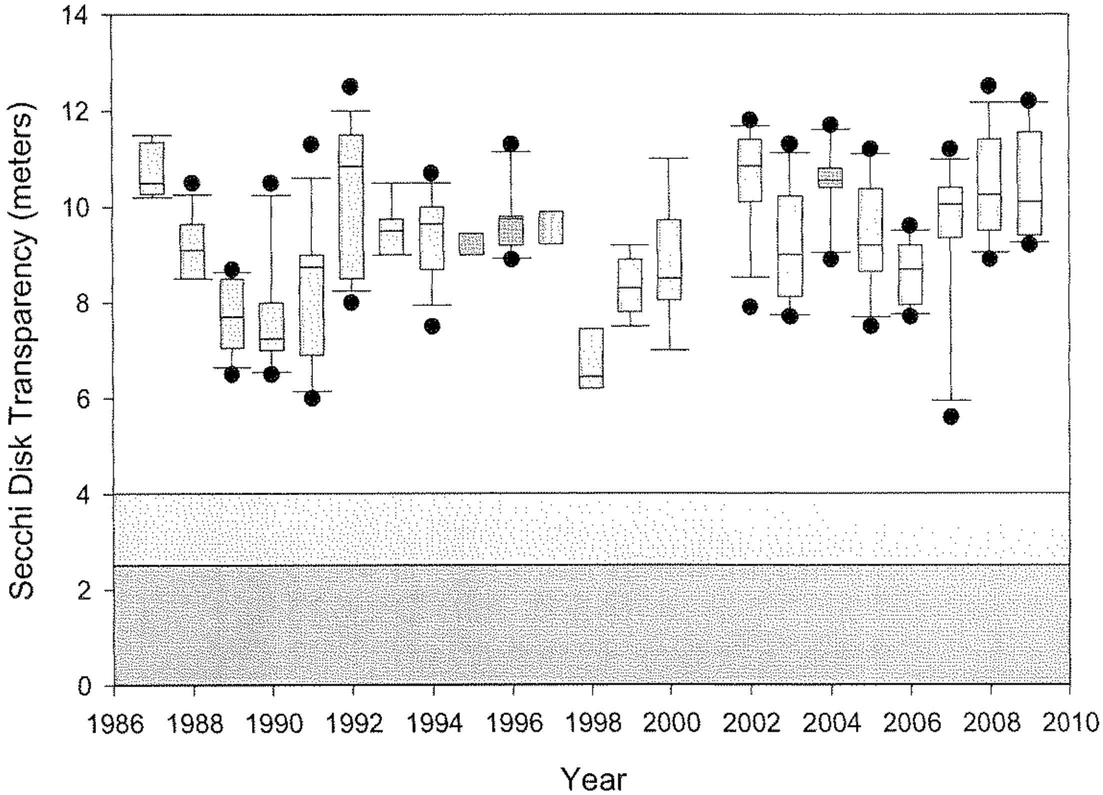

Great East - 2nd Basin
(2009 Seasonal Data)
Date
5/20/2009
6/3/2009
6/17/2009
7/1/2009
7/15/2009
7/29/2009
8/12/2009
8/26/2009
9/9/2009
9/23/2009
Secchi Disk Transparency (meters)
Dissolved Color (CPU)
0
2
4
6
8
10
12
14
16
18
54
48
42
36
30
24
18
12
6
0
Secchi Disk Transparency
Dissolved Color

Figure 18. Comparison of the annual Great East Lake, Site 1 Center, lay monitor Secchi Disk transparency data (1987-2009) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 19. Comparison of the annual Great East Lake, Site 1 Center, lay monitor Chlorophyll *a* data (1987-2009) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Great East Lake -- Site 1 Center
Annual Secchi Disk Transparency Comparisons
Box and Whisker Plots: 1987-2009



Great East Lake -- Site 1 Center
Annual Chlorophyll *a* Comparisons
Box and Whisker Plots: 1987-2009

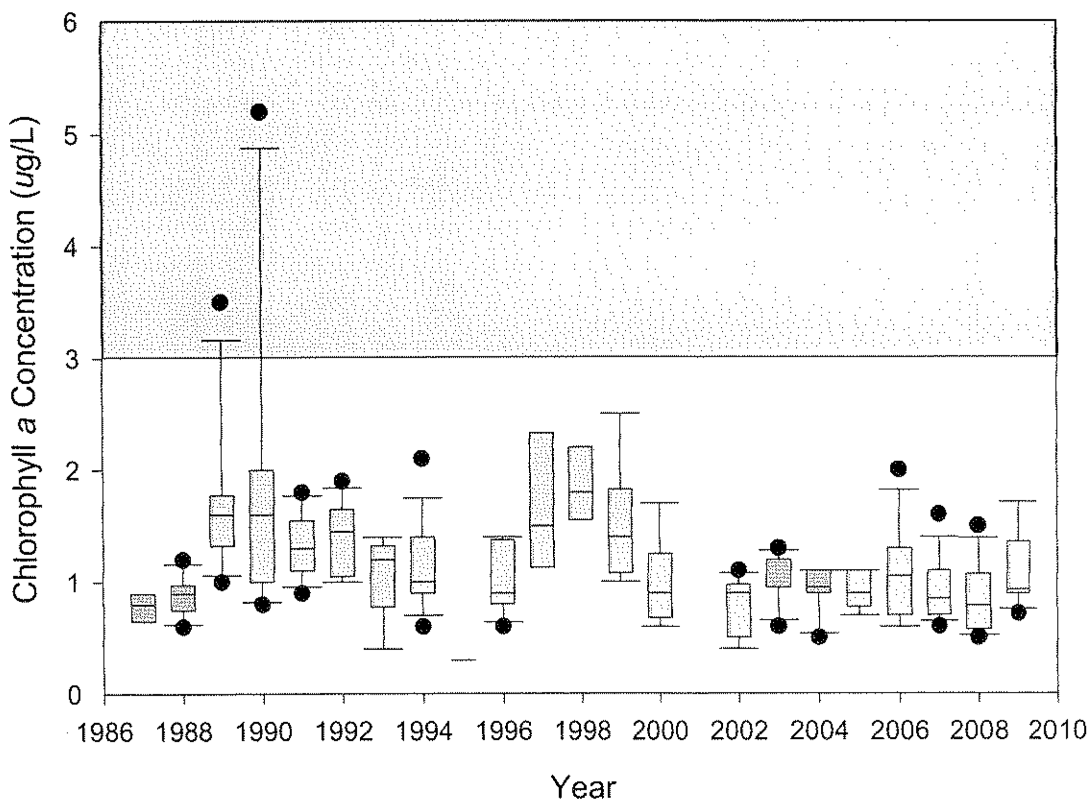
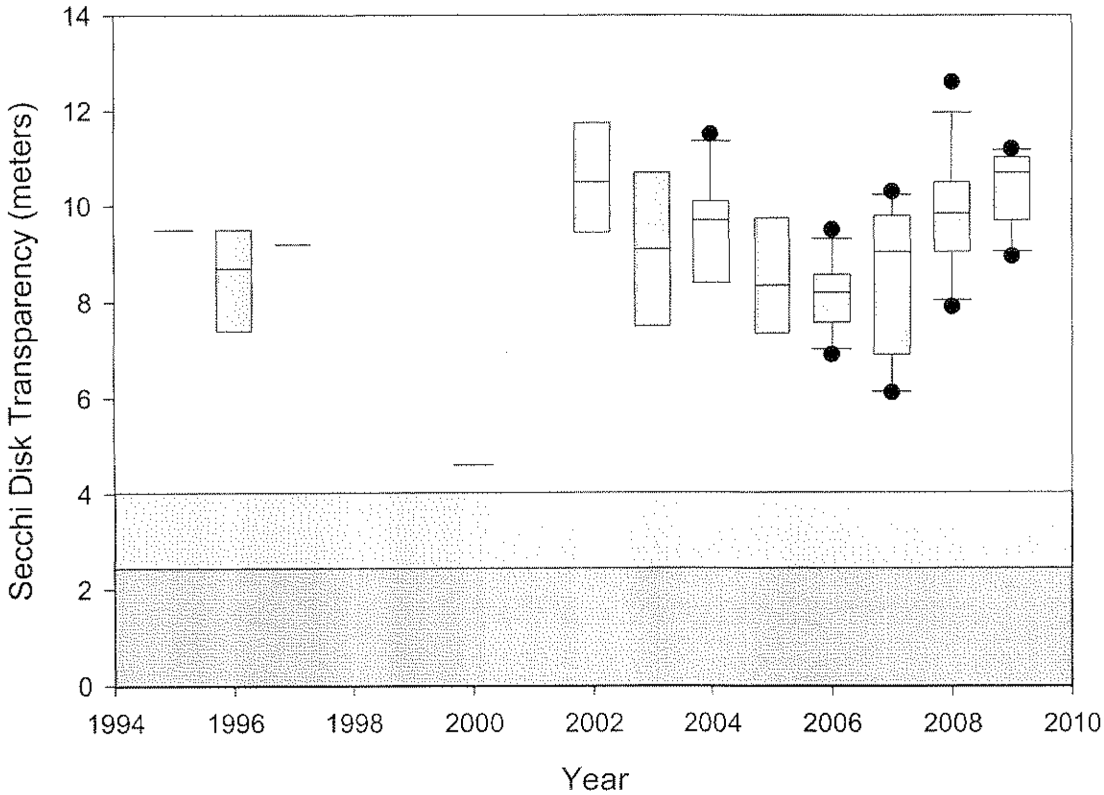


Figure 20. Comparison of the annual Great East Lake, Site 2 Canal Basin, lay monitor Secchi Disk transparency data (1995-2009) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 21. Comparison of the annual Great East Lake, Site 2 Canal Basin, lay monitor Chlorophyll *a* data (1995-2009) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Great East Lake -- Site 2 Canal
Annual Secchi Disk Transparency Comparisons
Box and Whisker Plots: 1995-2009



Great East Lake -- Site 2 Canal
Annual Chlorophyll *a* Comparisons
Box and Whisker Plots: 1995-2009

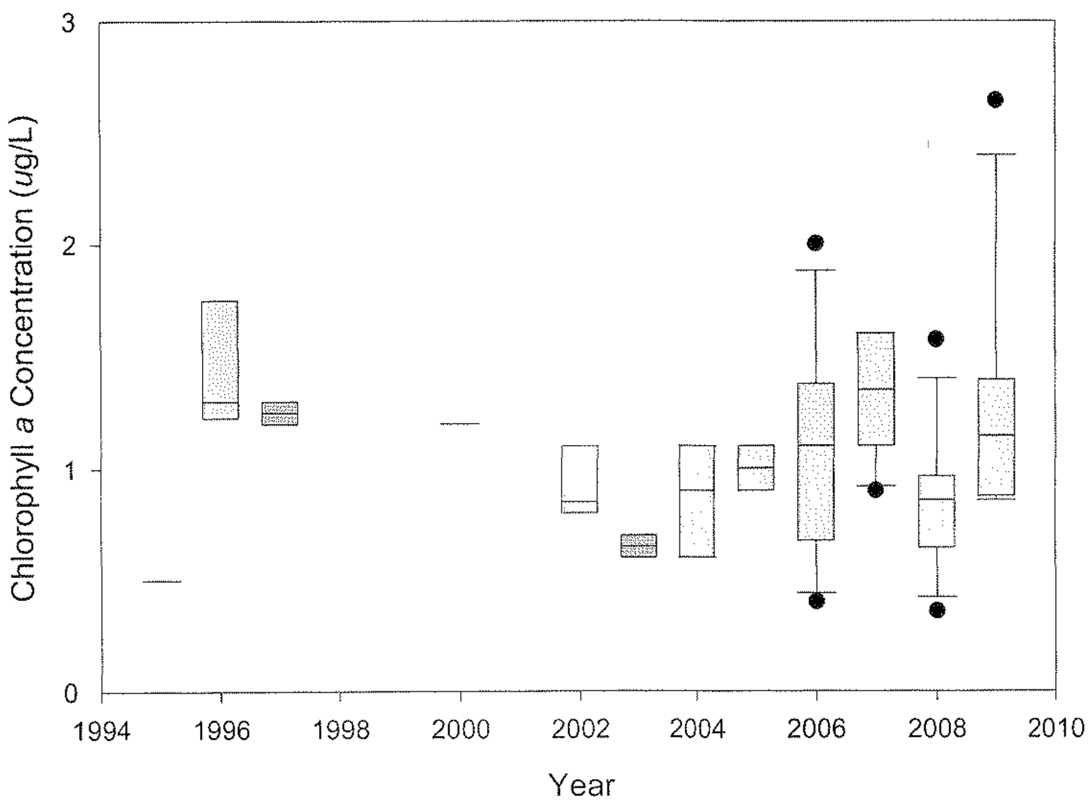
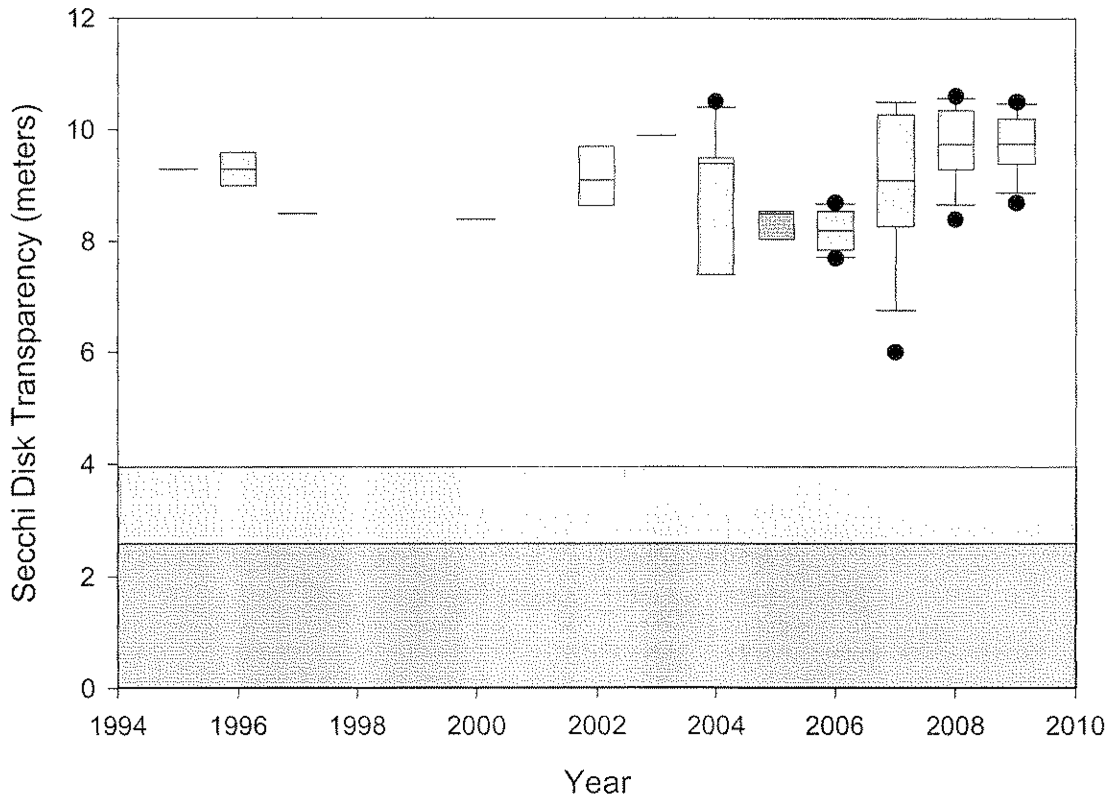


Figure 22. Comparison of the annual Great East Lake, Site 3 Maine Mann, lay monitor Secchi Disk transparency data (1995-2009) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 23. Comparison of the annual Great East Lake, Site 3 Maine Mann, lay monitor Chlorophyll *a* data (1995-2009) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Great East Lake -- Site 3 MMann
Annual Secchi Disk Transparency Comparisons
Box and Whisker Plots: 1995-2009



Great East Lake -- Site 3 MMann
Annual Chlorophyll *a* Comparisons
Box and Whisker Plots: 1995-2009

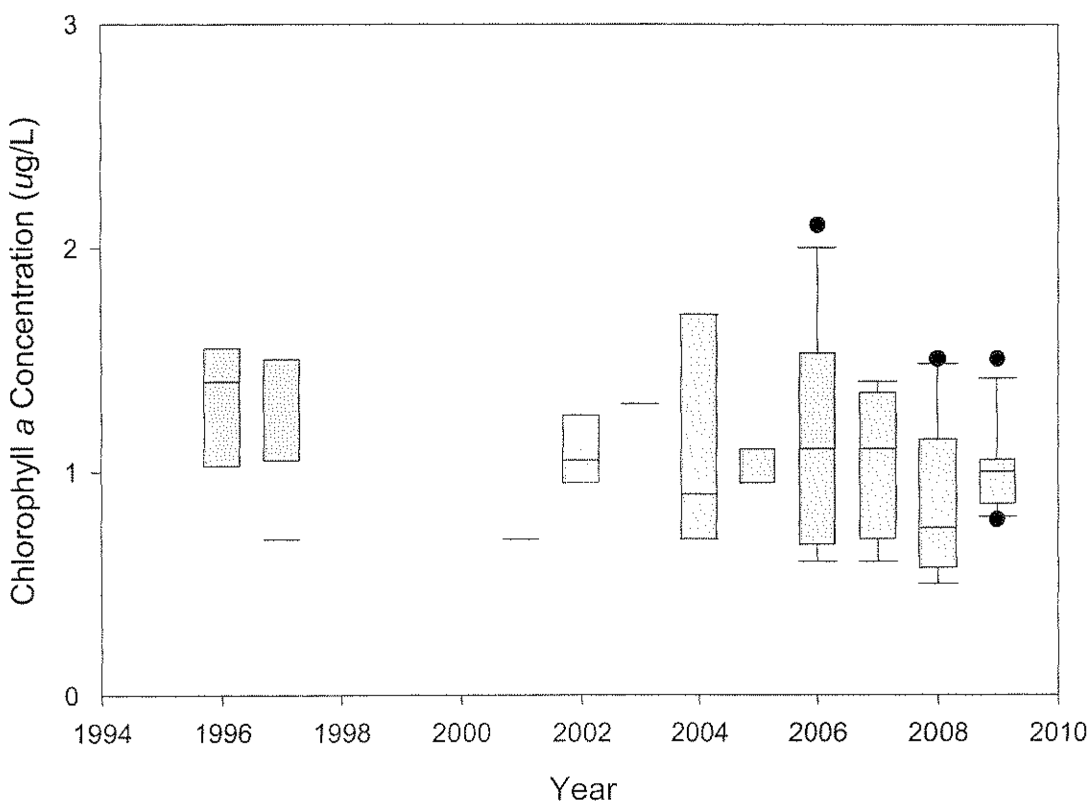
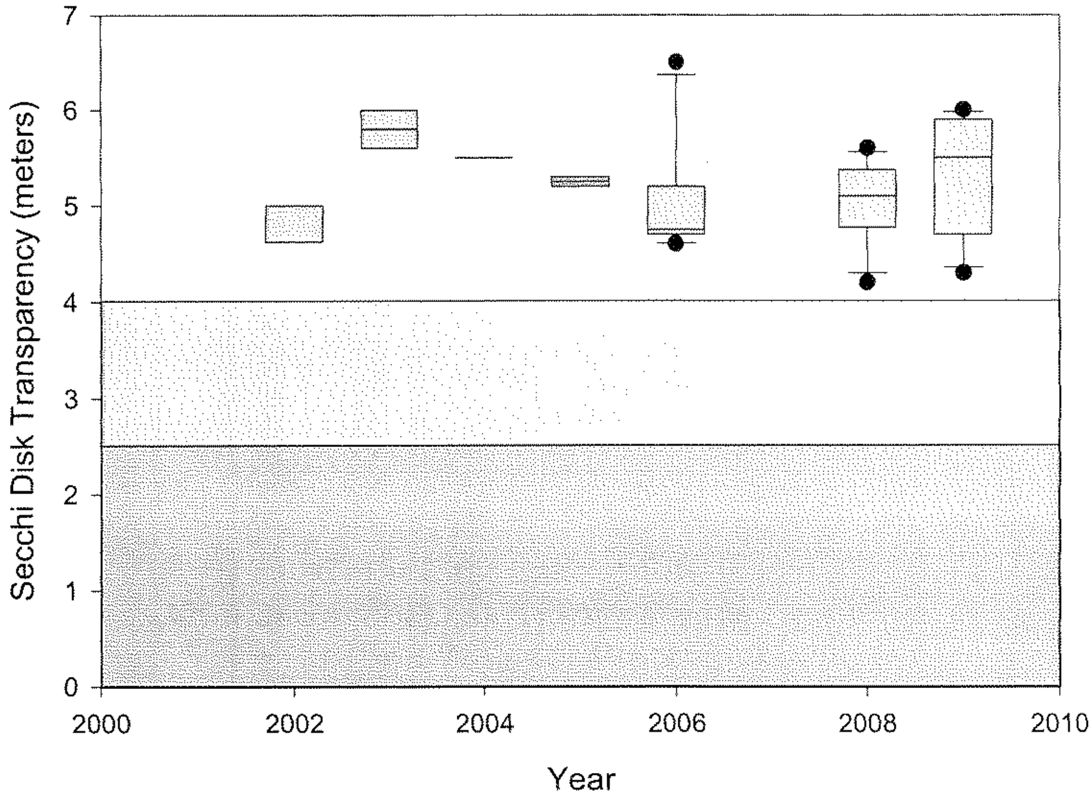


Figure 24. Comparison of the annual Great East Lake, Site 2nd Basin, lay monitor Secchi Disk transparency data (2002-2009) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 25. Comparison of the annual Great East Lake, Site 2nd Basin, lay monitor Chlorophyll *a* data (2002-2009) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Great East Lake -- Site Basin 2
Annual Secchi Disk Transparency Comparisons
Box and Whisker Plots: 2002-2009



Great East Lake -- Site Basin 2
Annual Chlorophyll *a* Comparisons
Box and Whisker Plots: 2002-2009

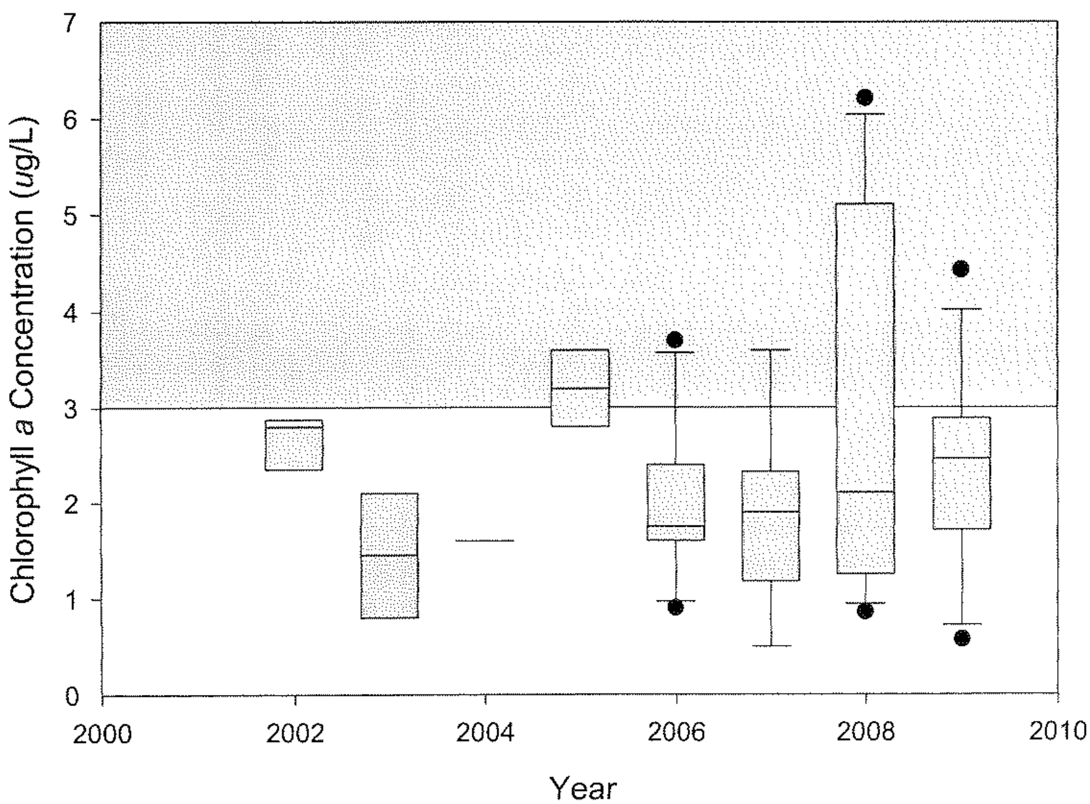
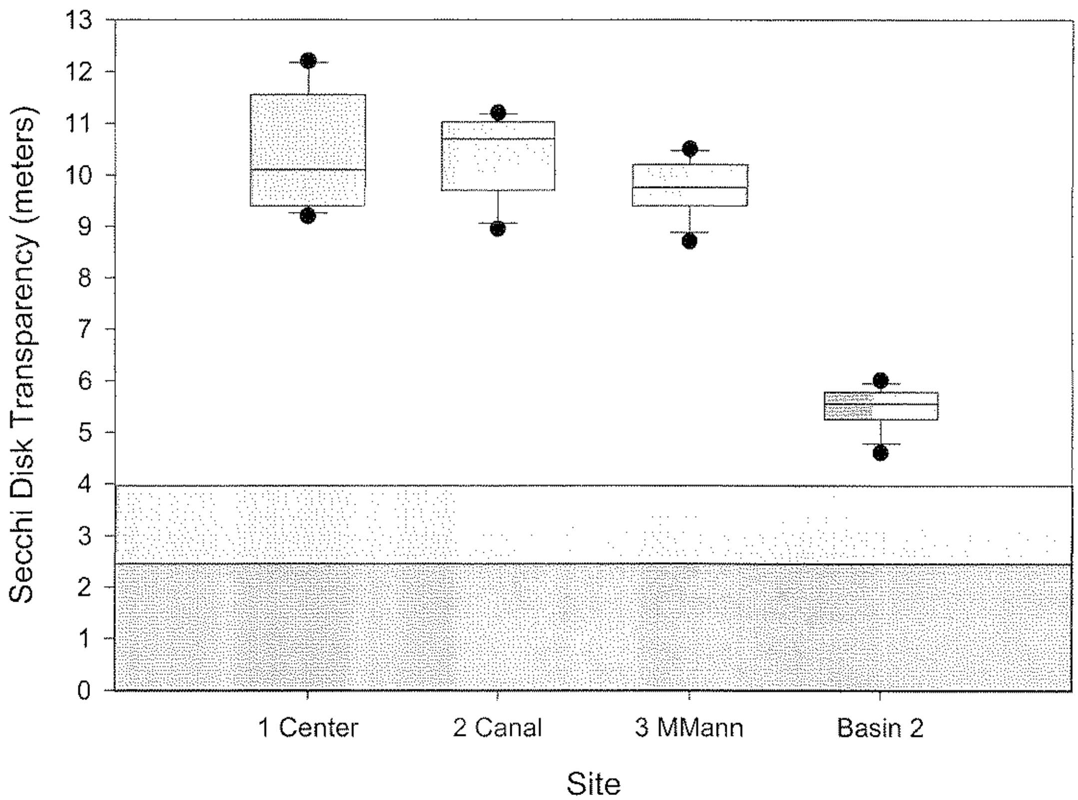


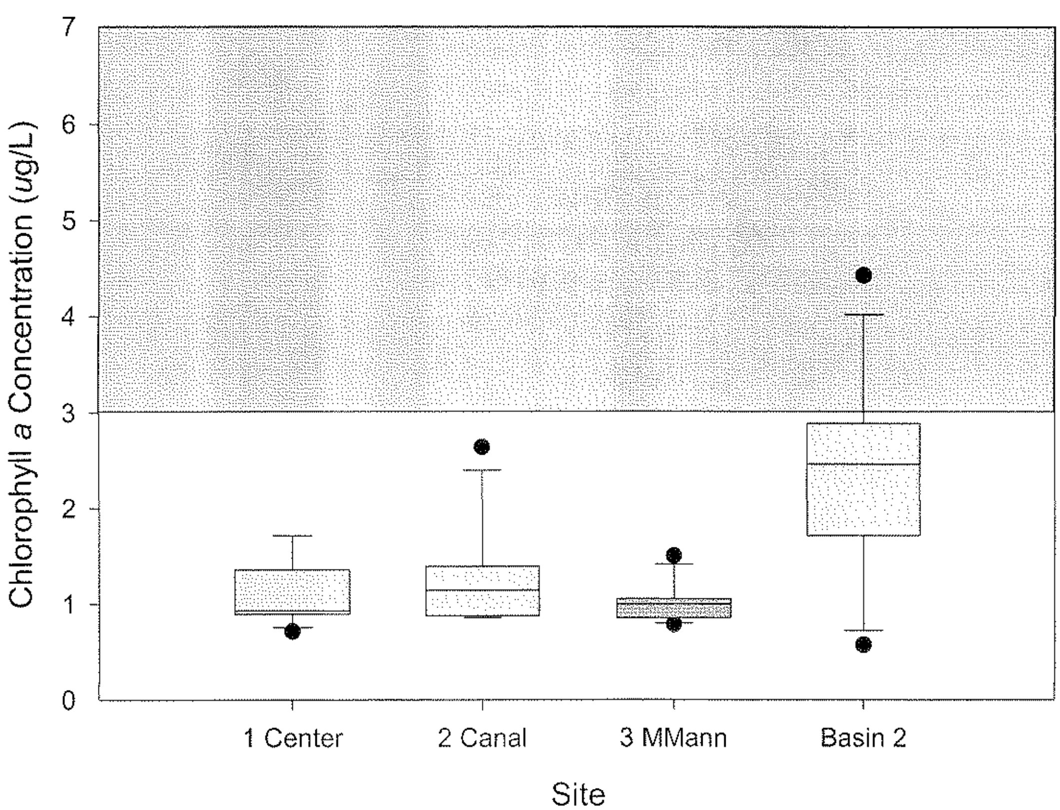
Figure 26. Great East Lake inter-site comparison of the 2009 lay monitor Secchi Disk transparency data that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 27. Great East Lake inter-site comparison of the 2009 lay monitor chlorophyll *a* data that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded) and moderately productive (light gray shading) lakes.

Great East Lake -- Inter-Site Comparison
Annual Secchi Disk Transparency Comparisons
Box and Whisker Plots: 2009

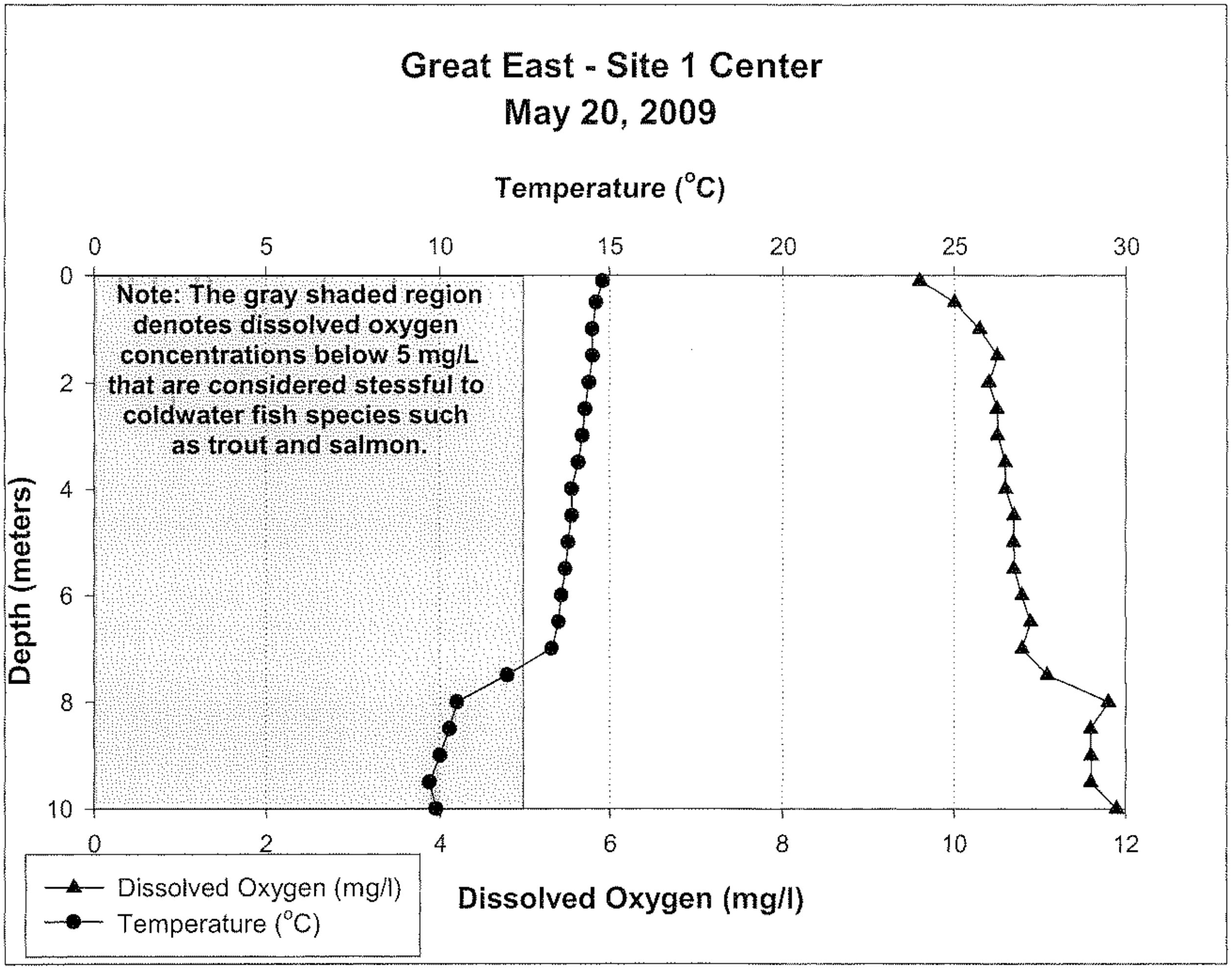


Great East Lake -- Inter-Site Comparison
Annual Chlorophyll *a* Comparisons
Box and Whisker Plots: 2009

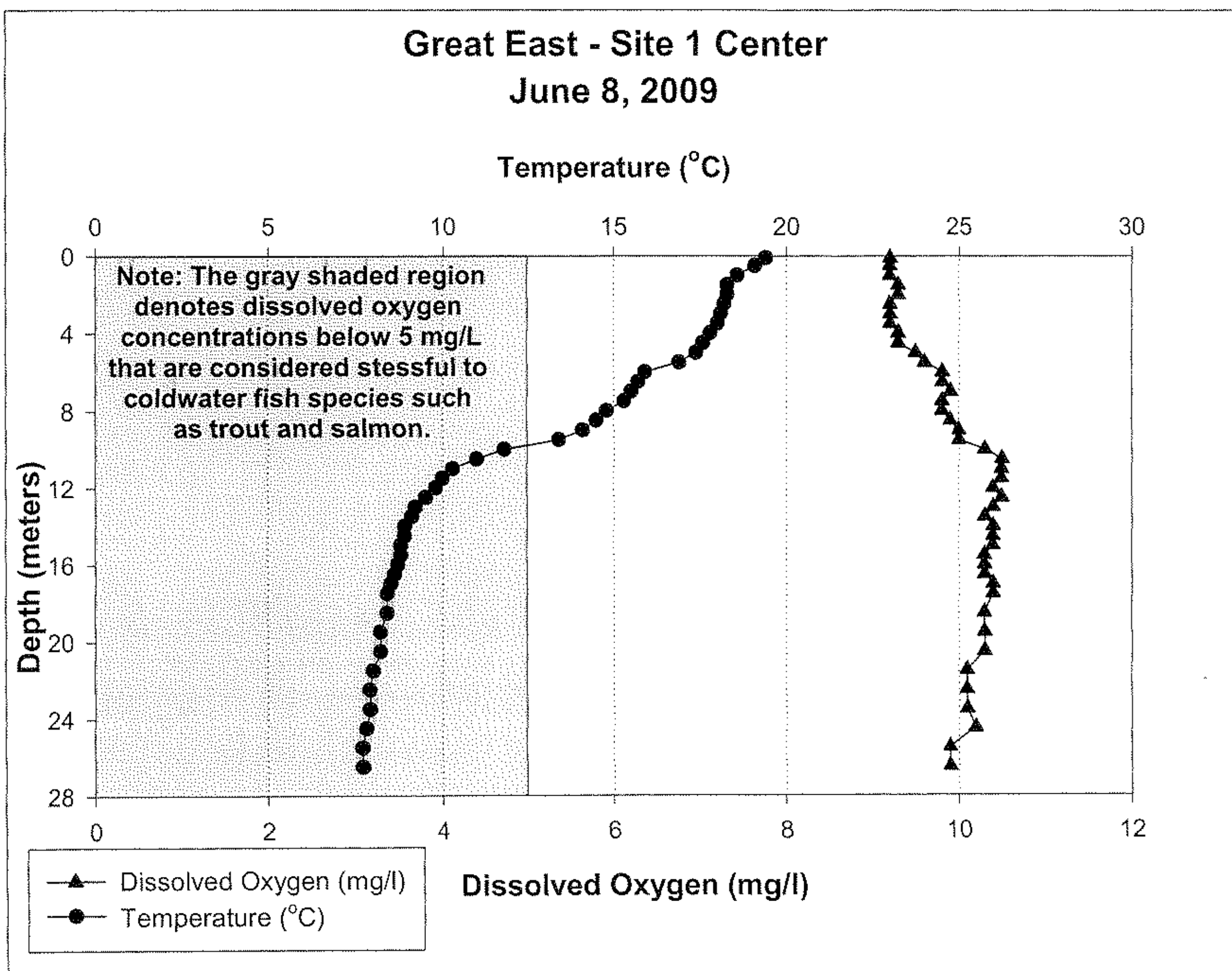


APPENDIX A

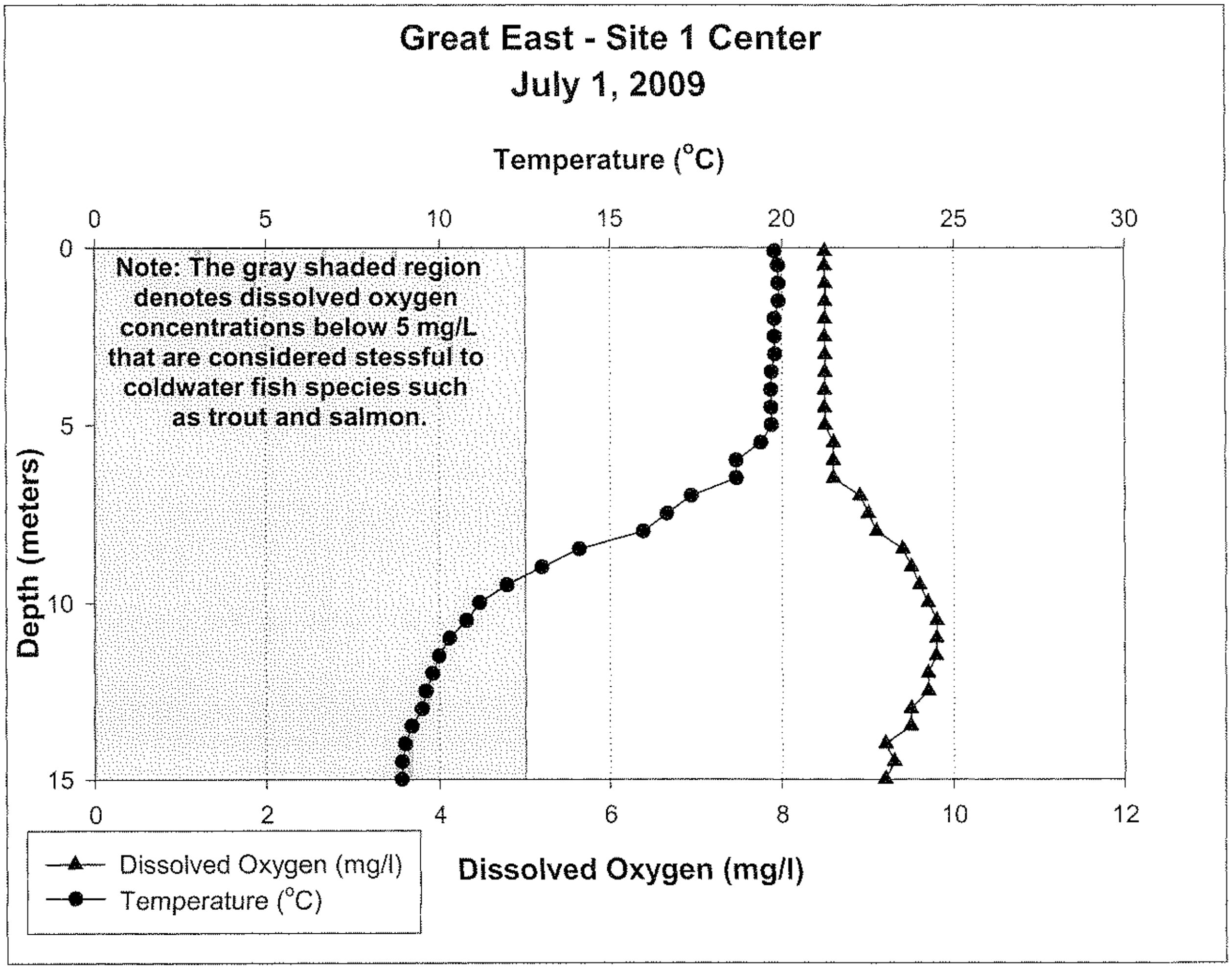
The following graphs illustrate the dissolved oxygen and temperature data collected at the Great East Lake deep sampling stations, Sites 1 Center, 2 Canal Basin, 3 Maine Mann and 2nd Basin, between May 20 and September 26, 2009. Temperature and dissolved oxygen data were generally collected at one-half meter intervals from the surface down to the lake bottom. The temperature units are degrees Celsius (^{o}C) while the dissolved oxygen units are milligrams per liter (mg/l). The gray shaded region on the graphs represents dissolved oxygen concentrations stressful to coldwater fish species (dissolved oxygen concentrations less than 5 parts per million). *Notice changes in dissolved oxygen concentration, near the lake bottom, among sampling dates.*

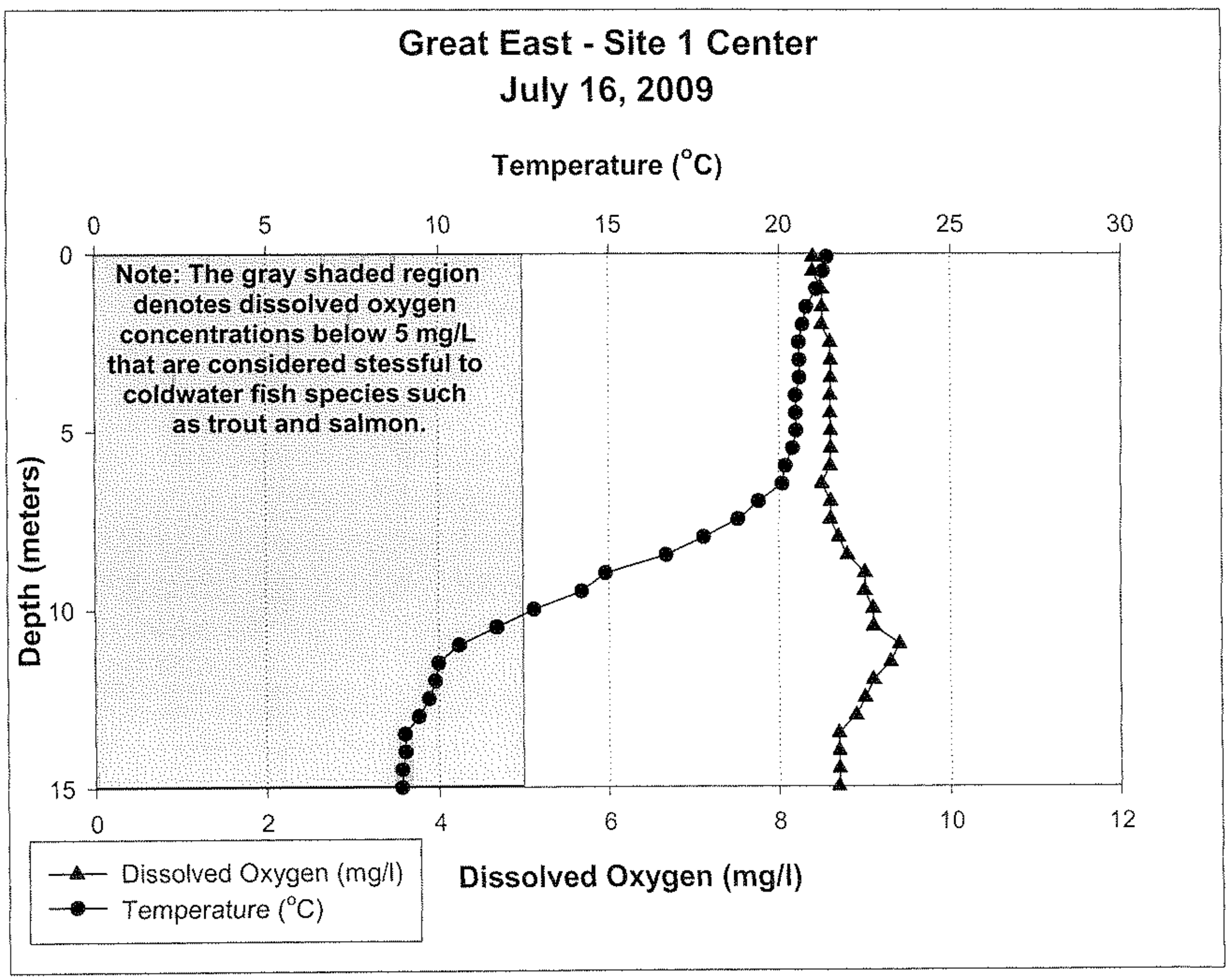


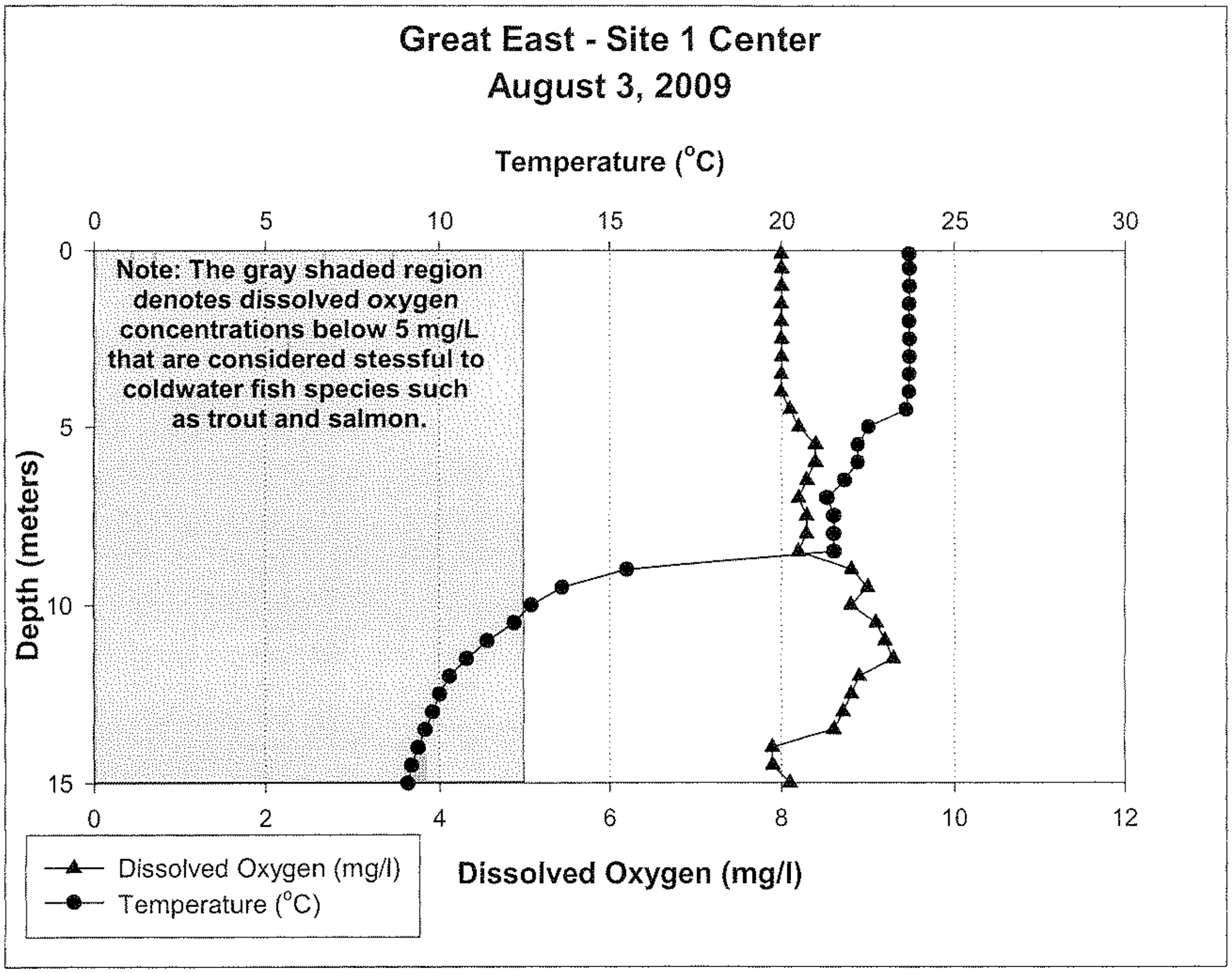
Great East - Site 1 Center
May 20, 2009
Temperature (°C)
0 5 10 15 20 25 30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0 2 4 6 8 10
0 2 4 6 8 10 12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

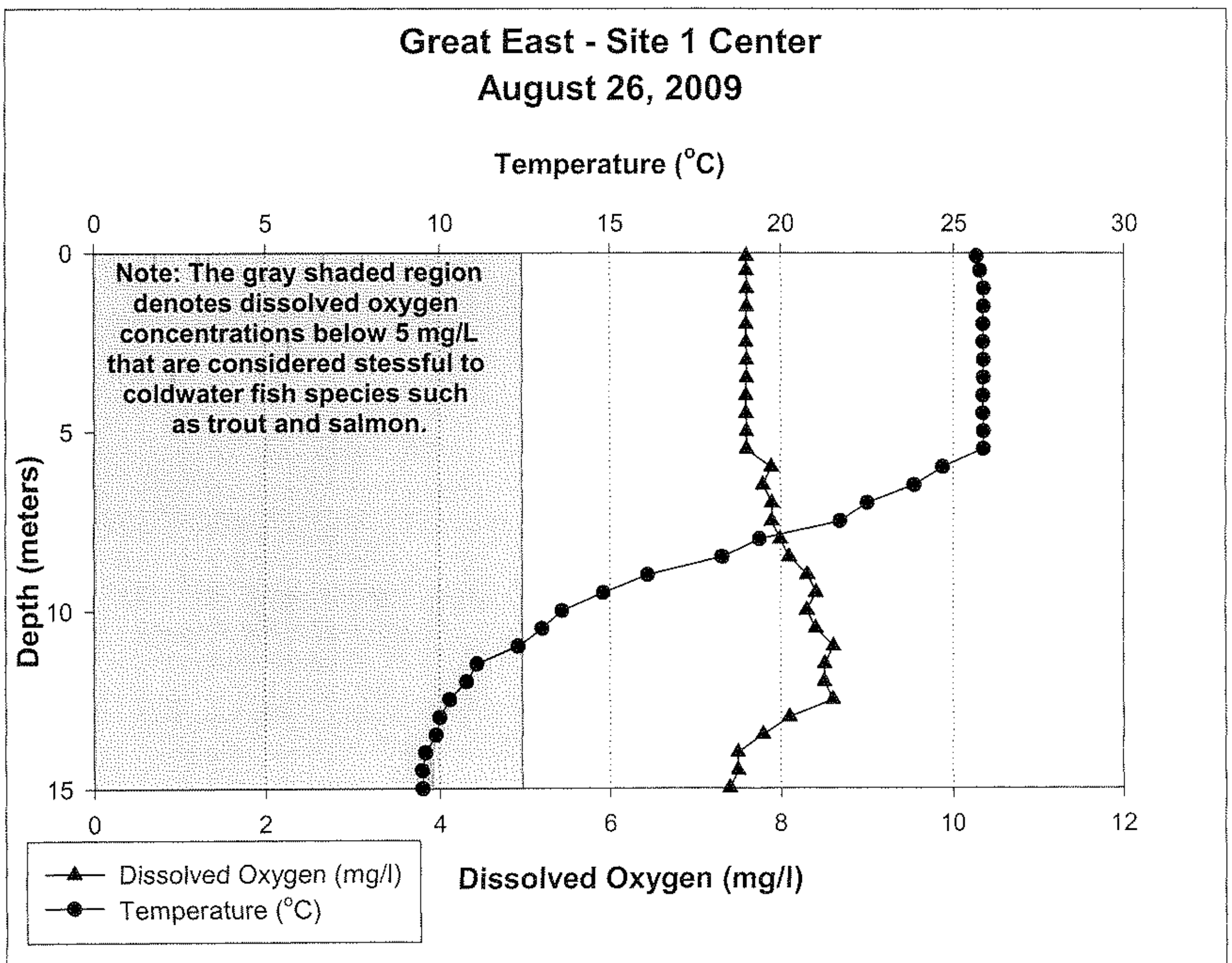


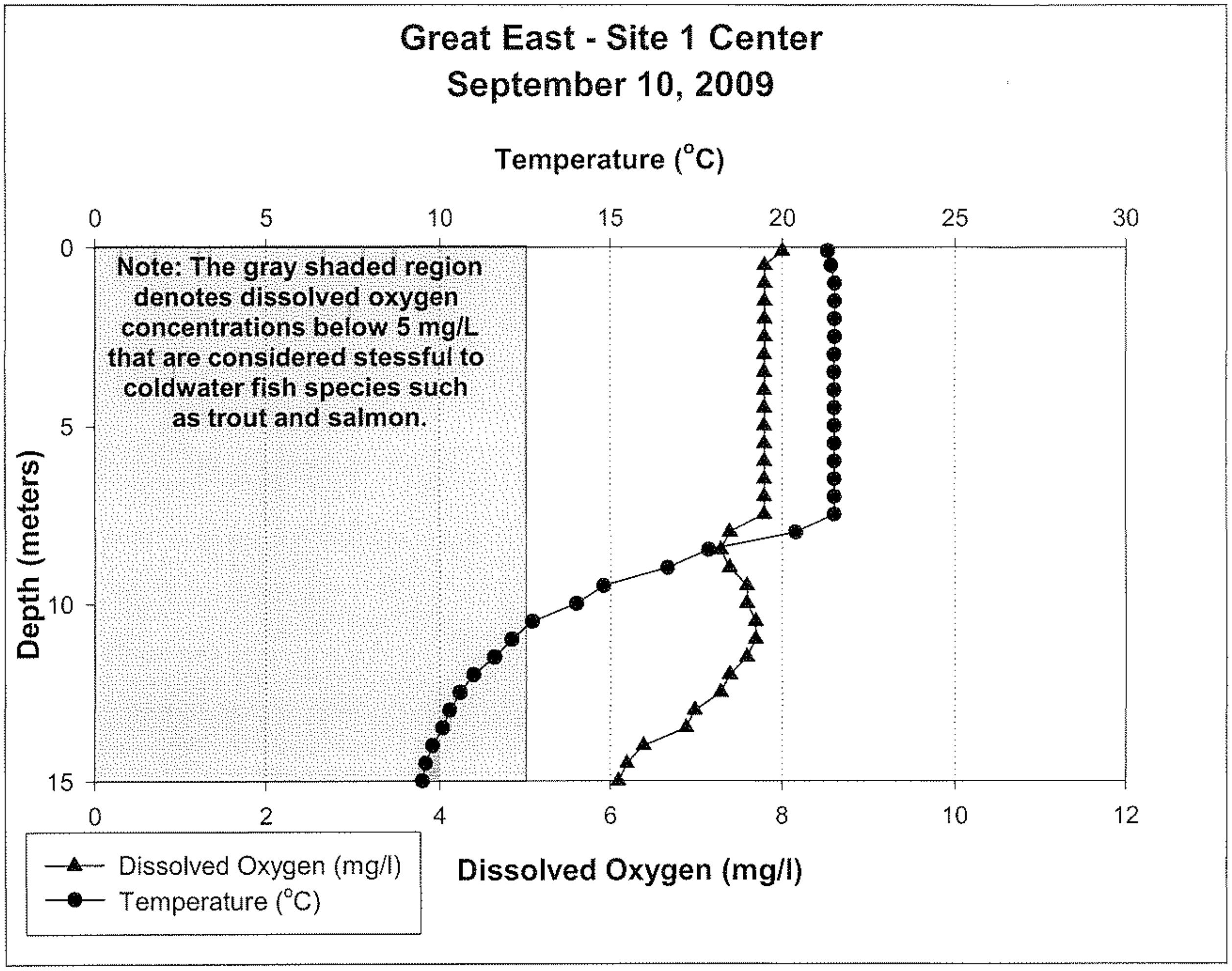
Great East - Site 1 Center
June 8, 2009
Temperature (°C)
0 5 10 15 20 25 30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0 4 8 12 16 20 24 28
0 2 4 6 8 10 12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

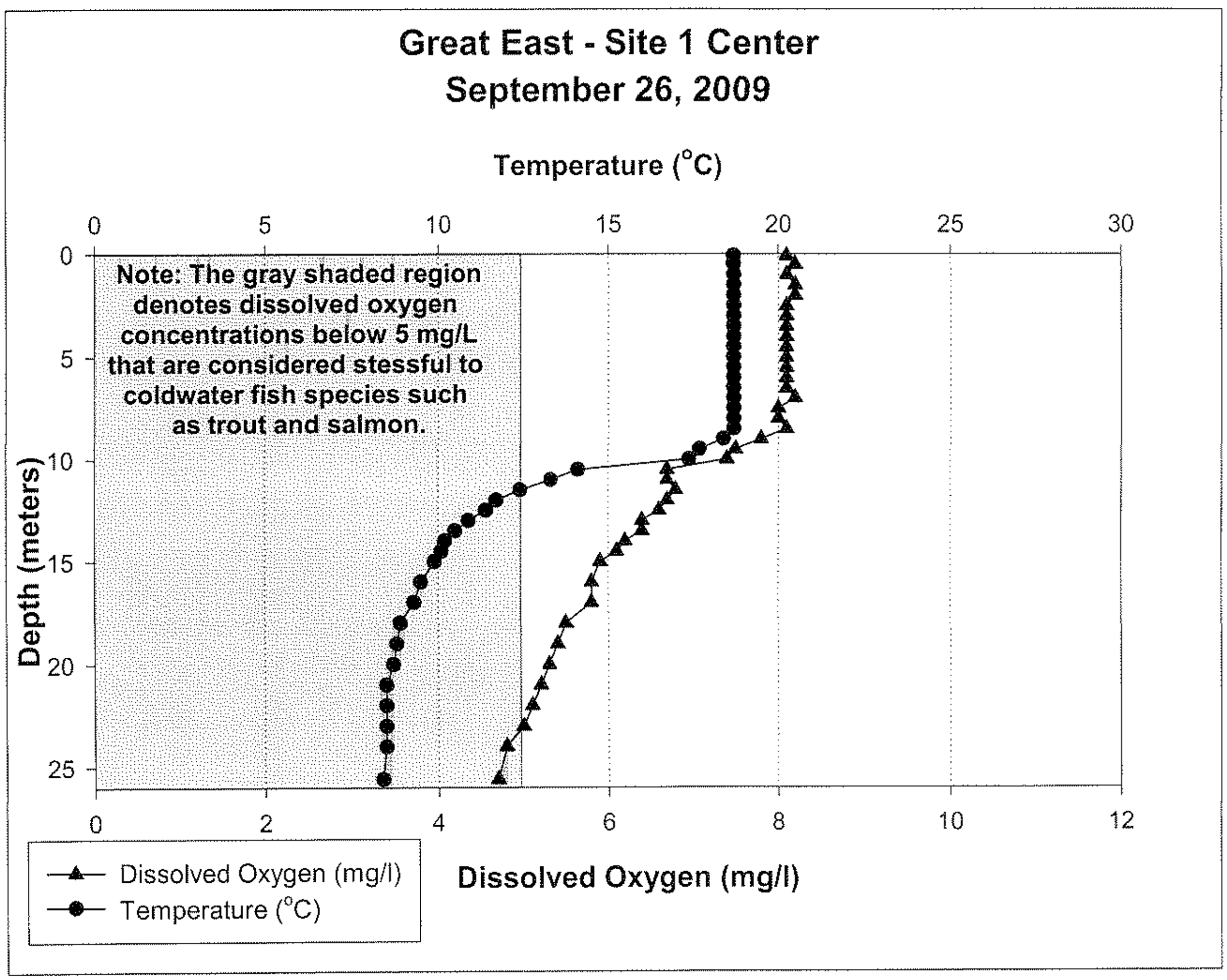

Great East - Site 1 Center
July 1, 2009
Temperature (°C)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

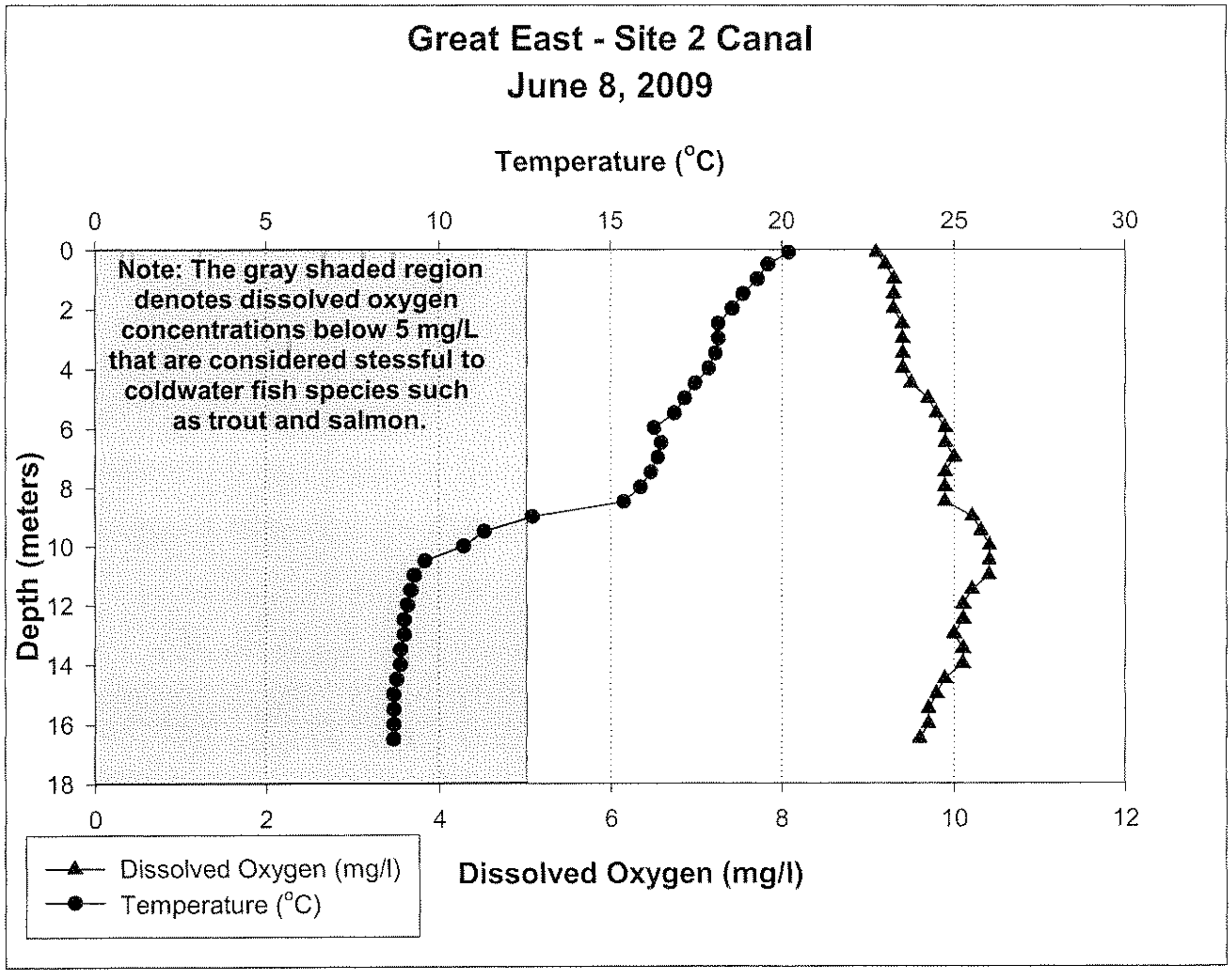

Great East - Site 1 Center
July 16, 2009
Temperature (°C)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

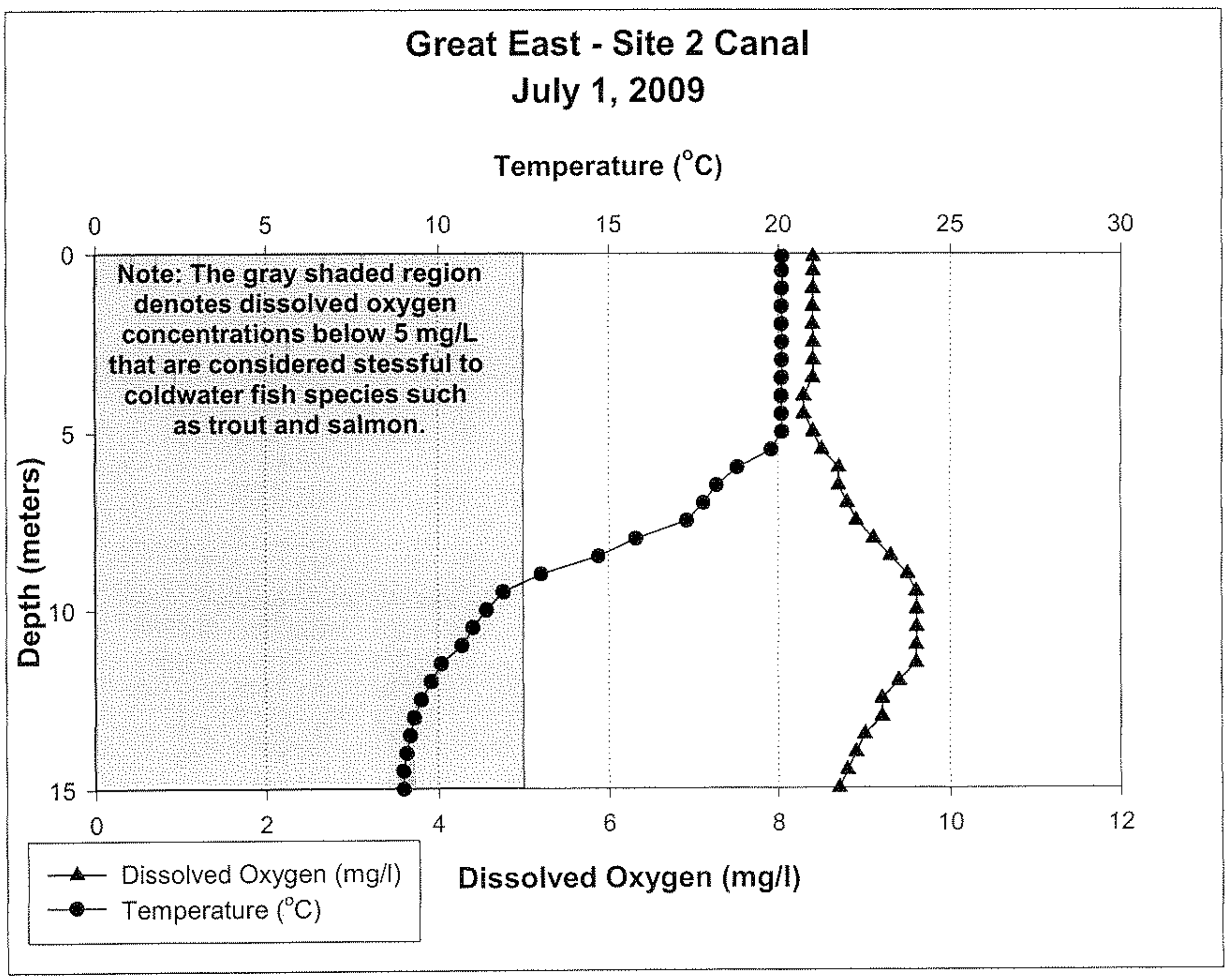

Great East - Site 1 Center
August 3, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
5
10
15
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

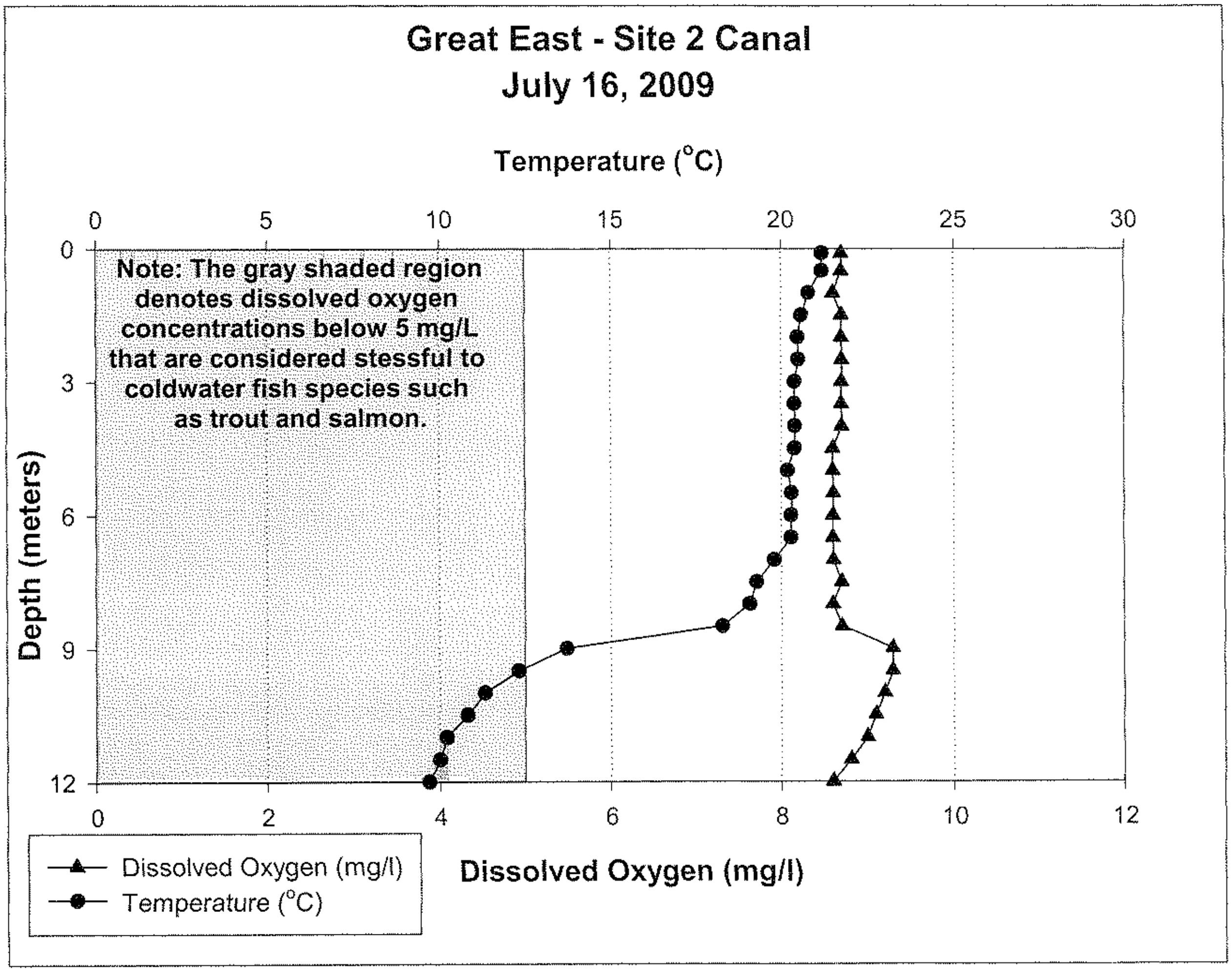

Great East - Site 1 Center
August 26, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
5
10
15
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

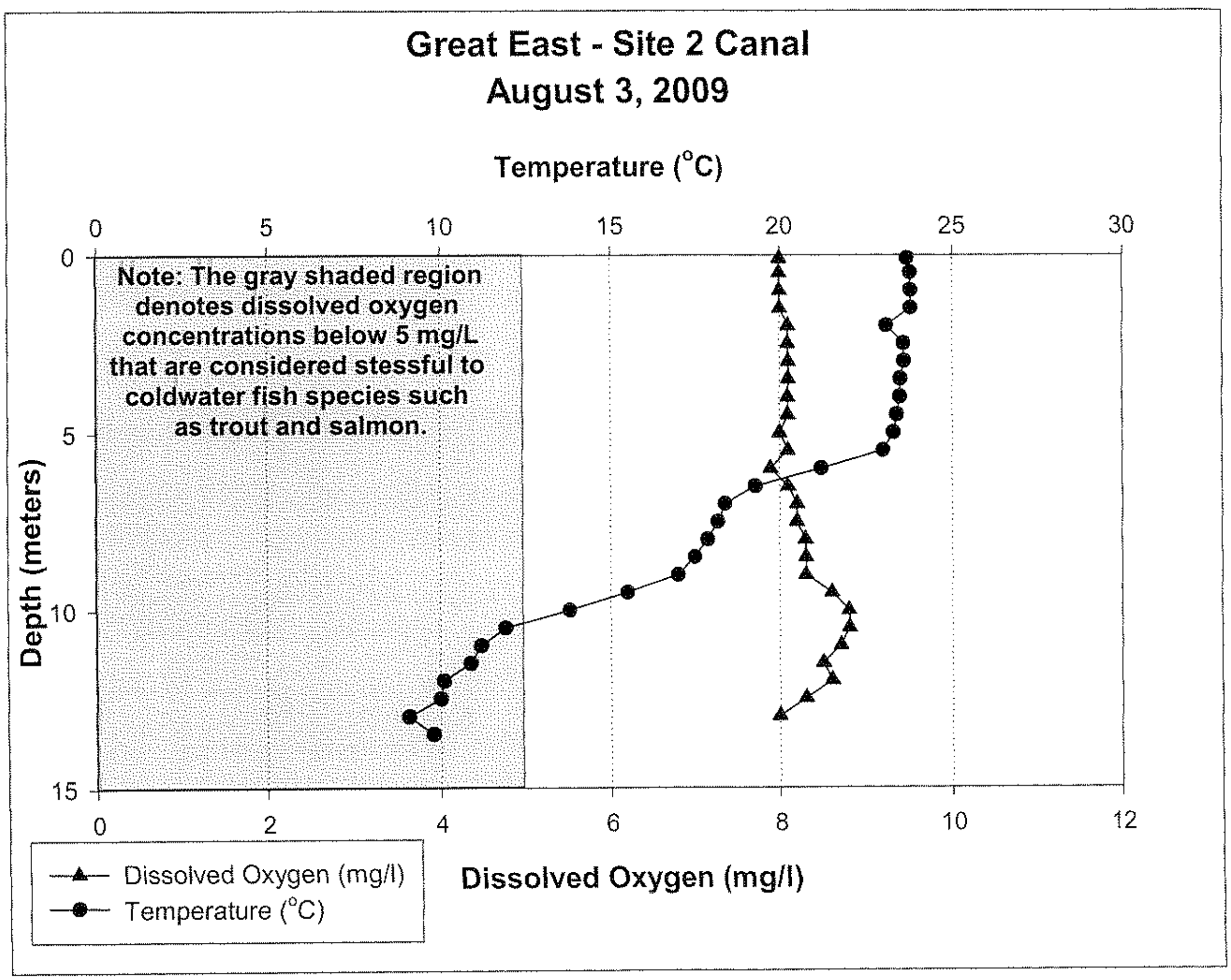

Great East - Site 1 Center
September 10, 2009
Temperature (°C)
0 5 10 15 20 25 30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0 5 10 15
0 2 4 6 8 10 12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

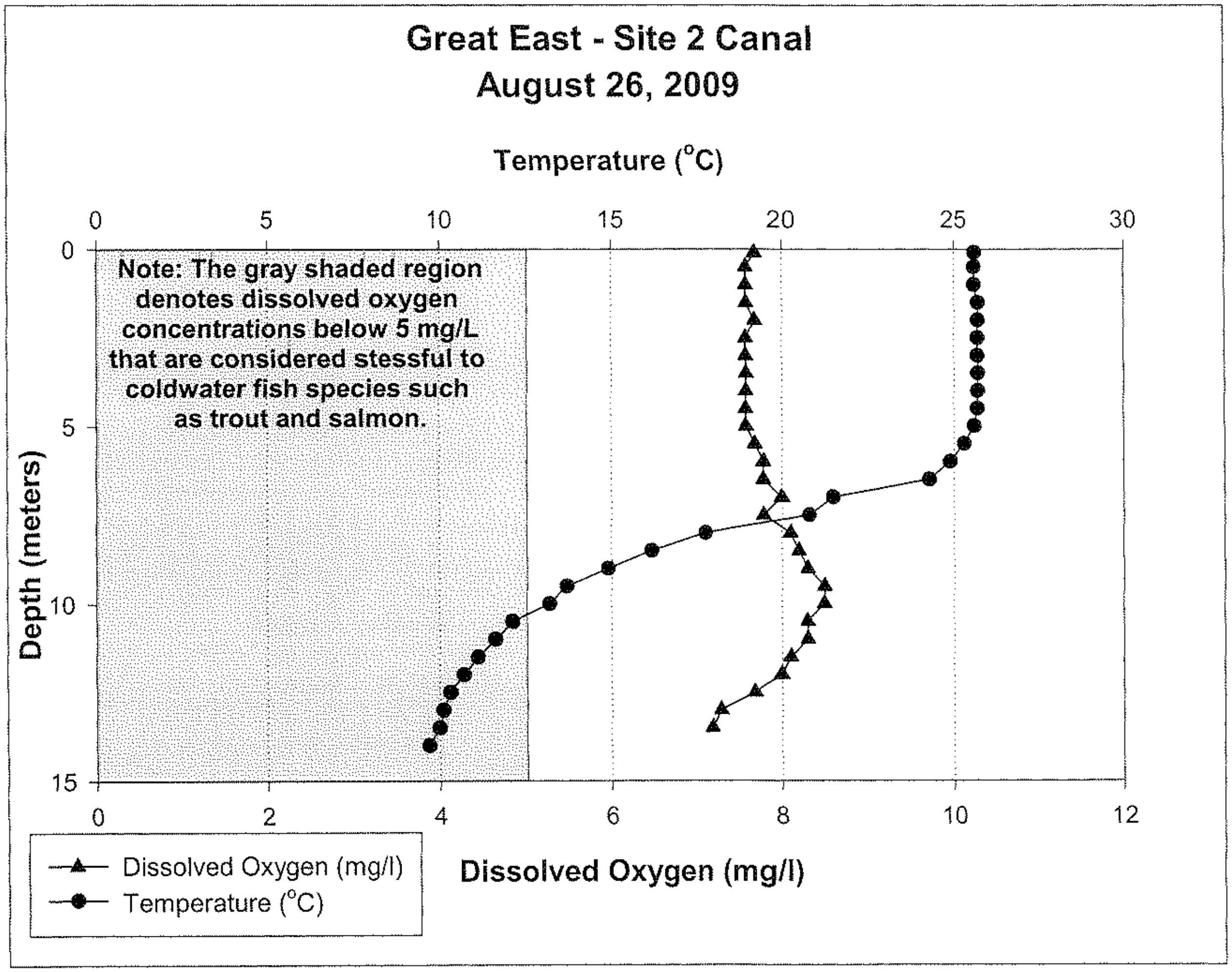

Great East - Site 1 Center
September 26, 2009
Temperature (°C)
0 5 10 15 20 25 30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0 5 10 15 20 25
0 2 4 6 8 10 12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)


Great East - Site 2 Canal
June 8, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
2
4
6
8
10
12
14
16
18
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Dissolved Oxygen (mg/l)
Temperature (°C)

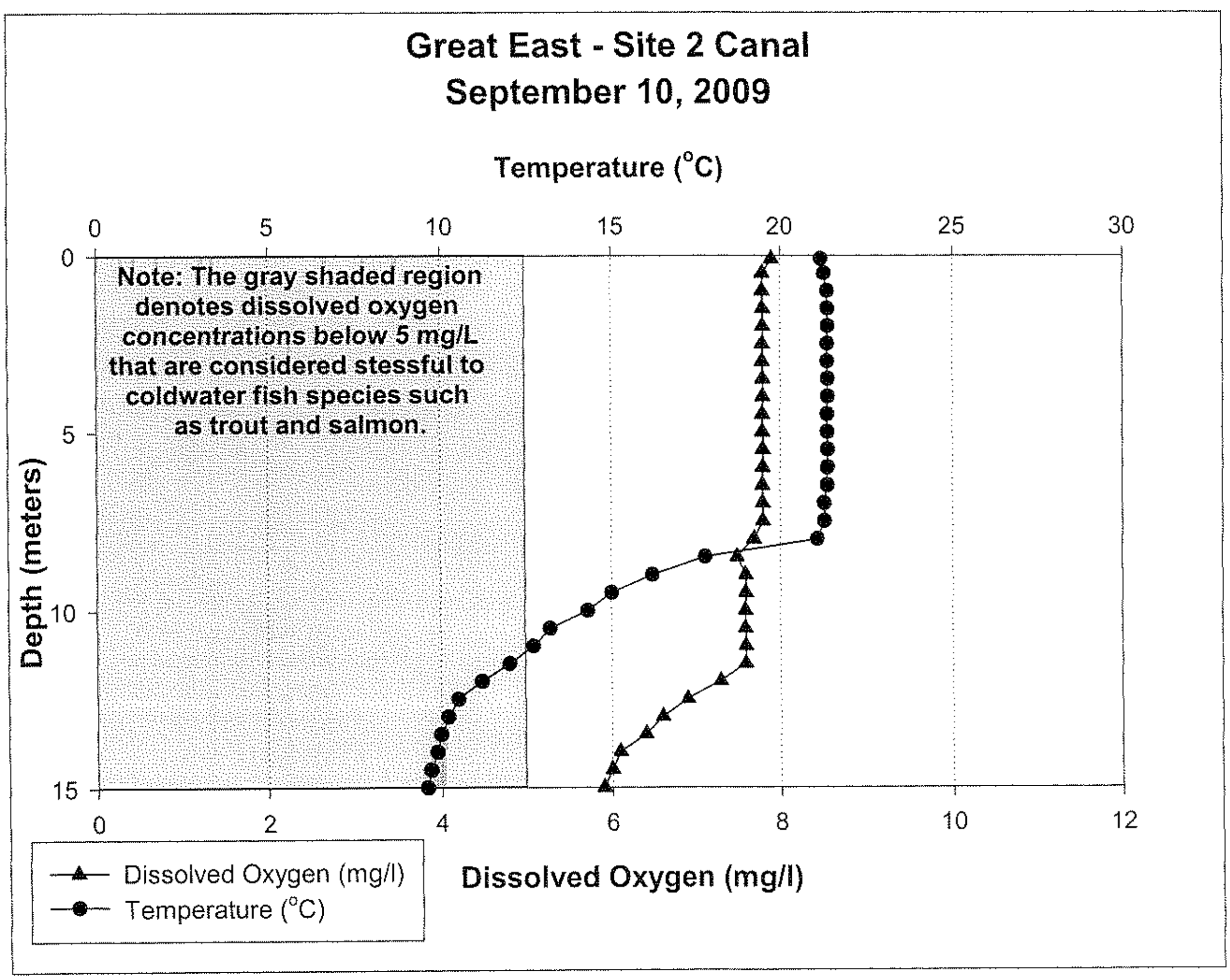

Great East - Site 2 Canal
July 1, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
5
10
15
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Dissolved Oxygen (mg/l)
Temperature (°C)


Great East - Site 2 Canal
July 16, 2009
Temperature (°C)
0
5
10
15
20
25
30
0
3
6
9
12
Depth (meters)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

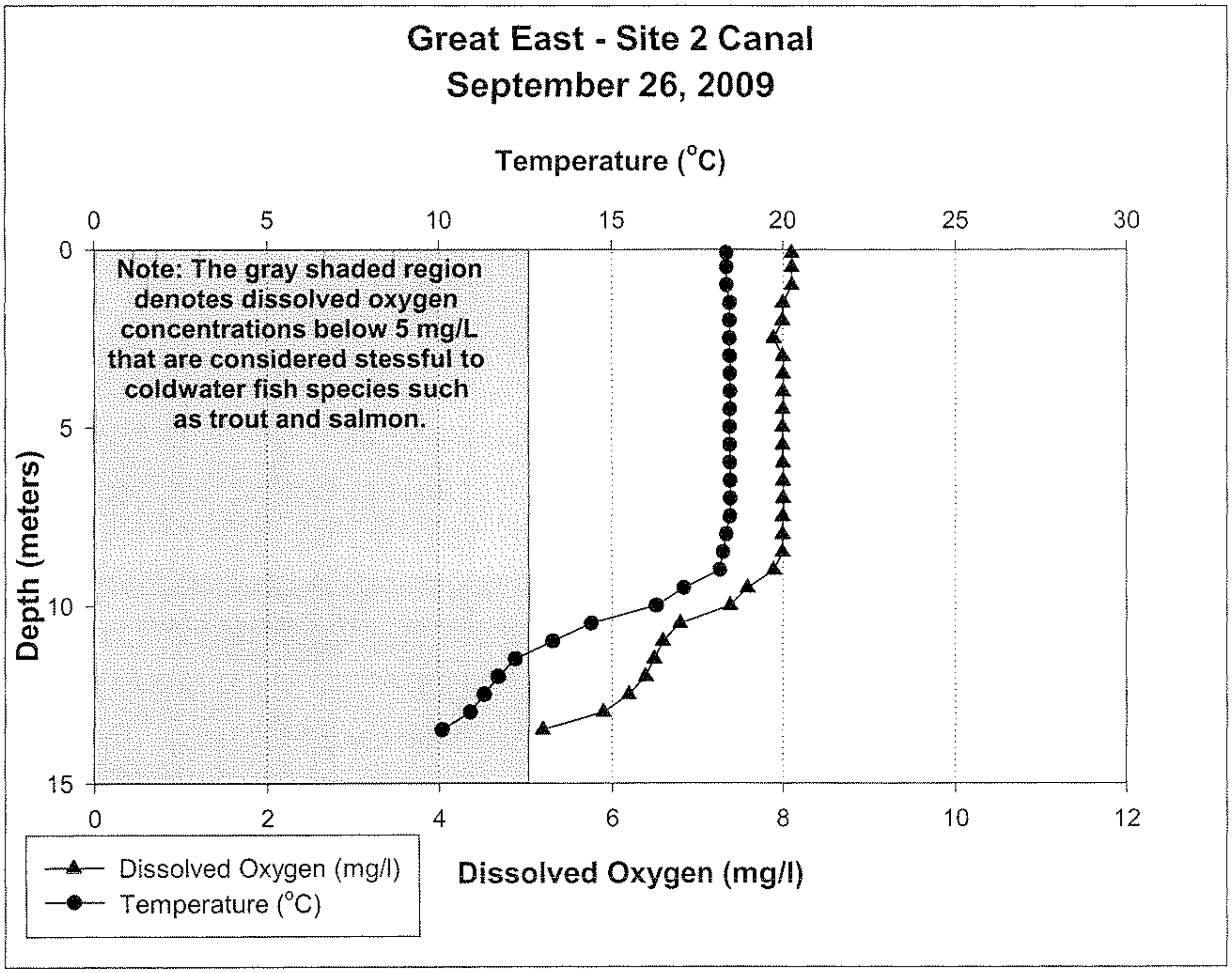

Great East - Site 2 Canal
August 3, 2009
Temperature (°C)
0
5
10
15
20
25
30
0
5
10
15
Depth (meters)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)



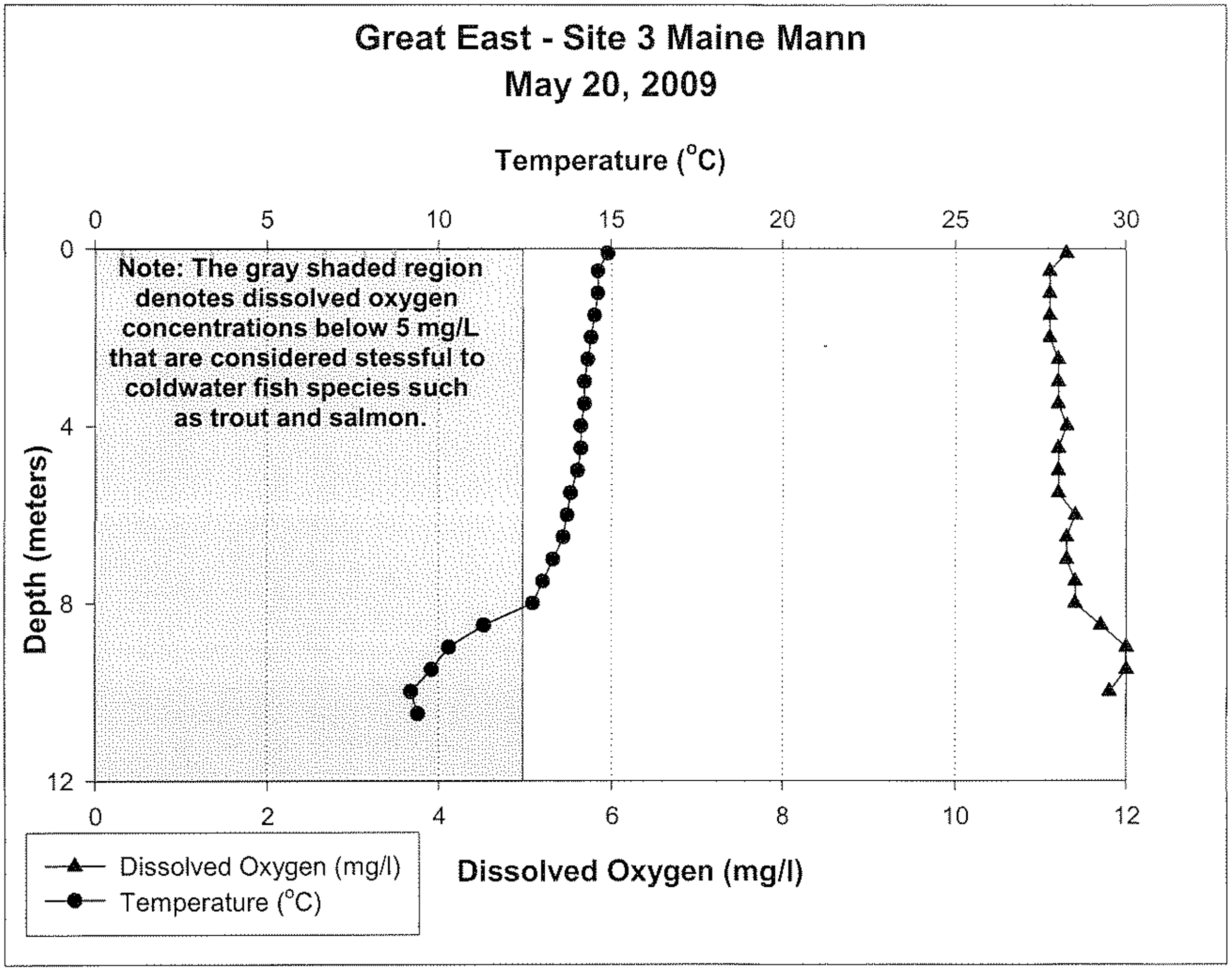
Great East - Site 2 Canal
August 26, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
5
10
15
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)



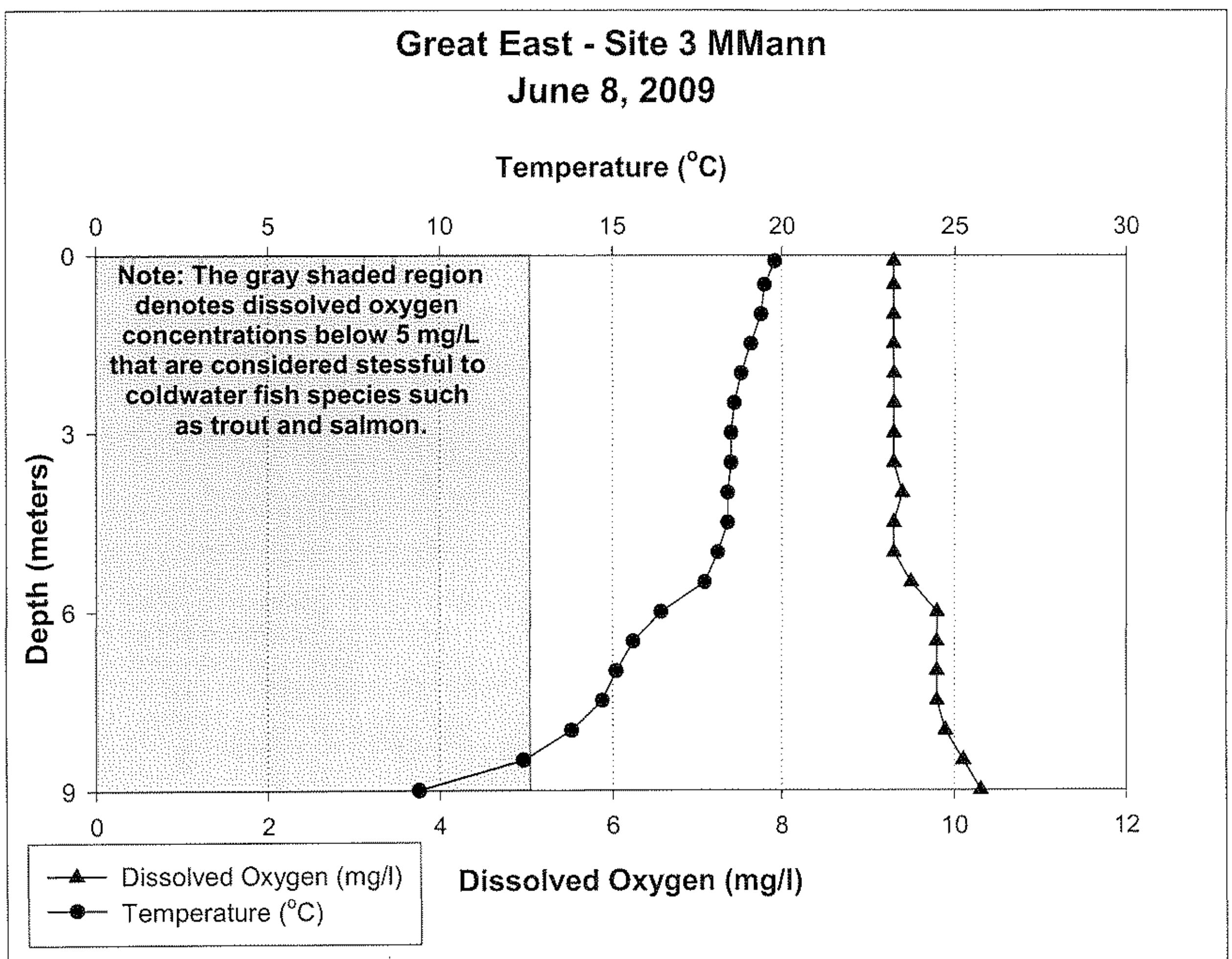
Great East - Site 2 Canal
September 10, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
5
10
15
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)



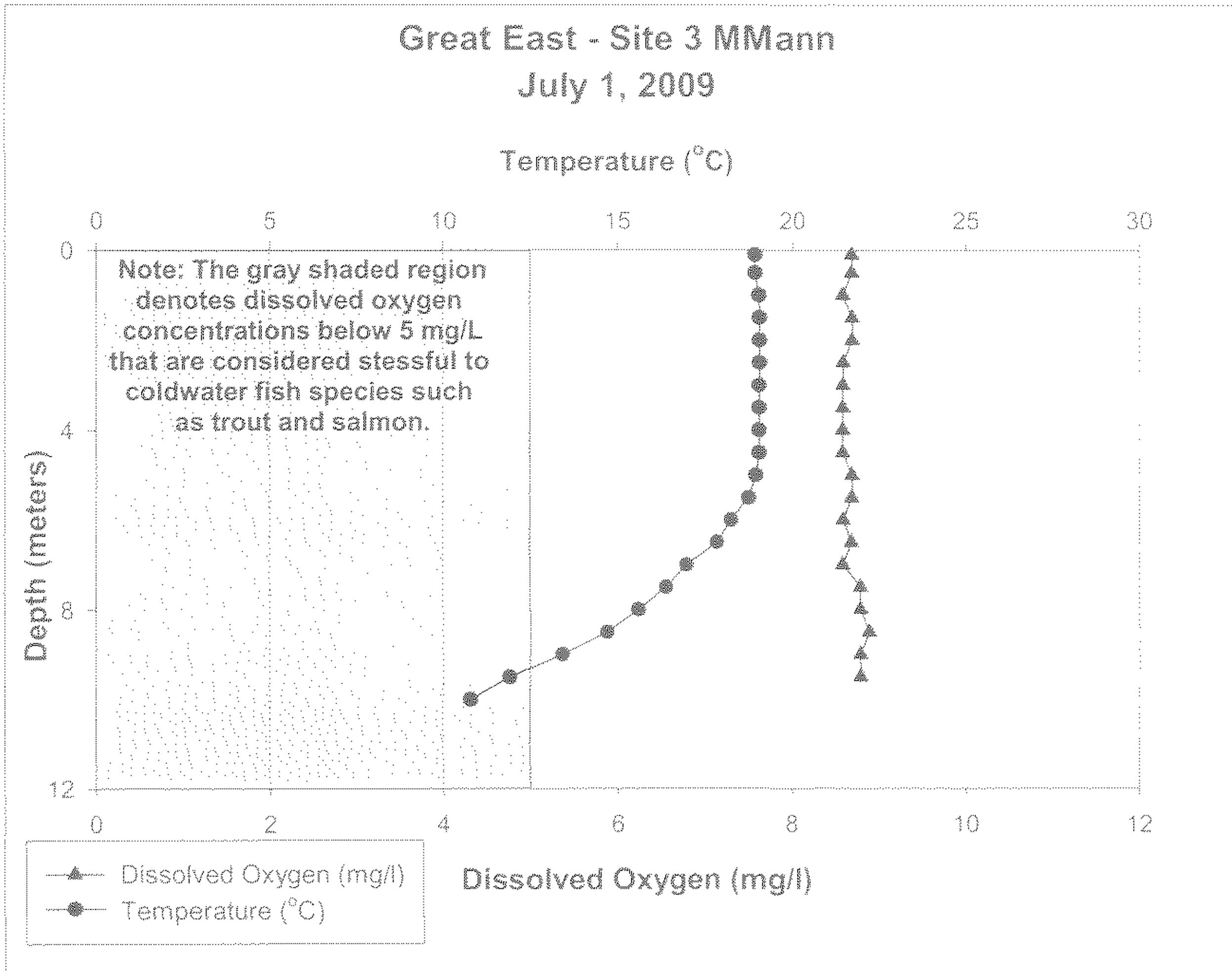
Great East - Site 2 Canal
September 26, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
5
10
15
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

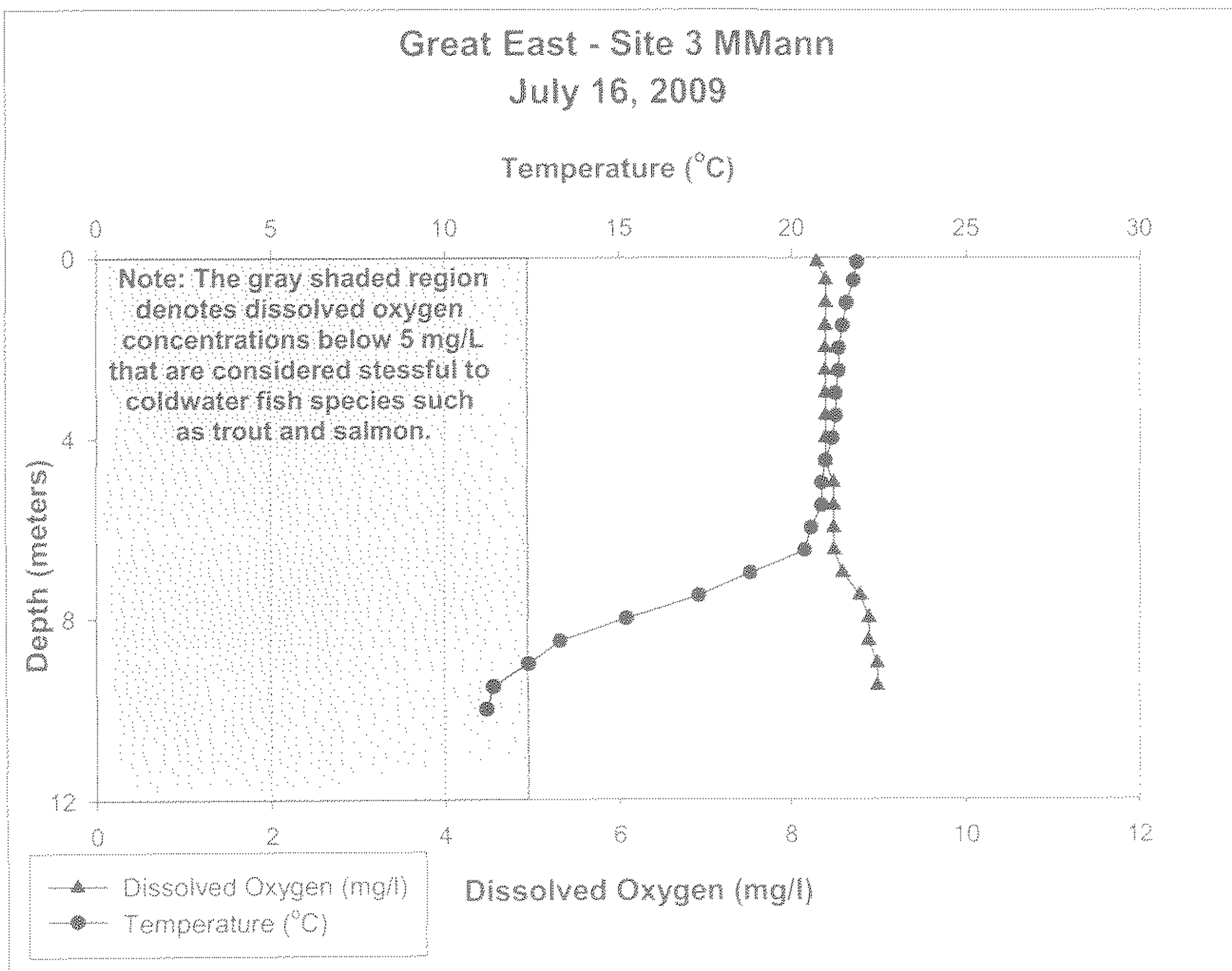


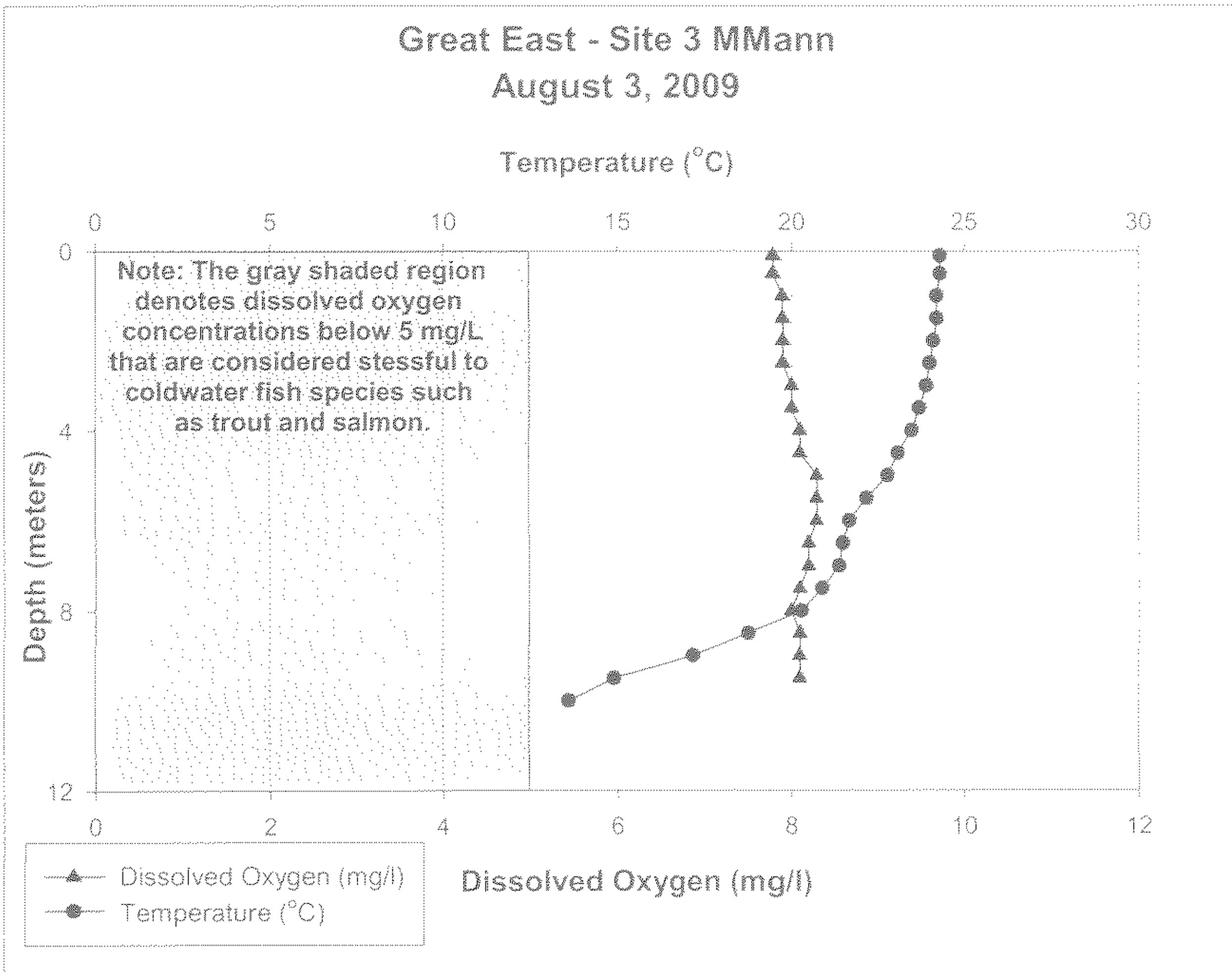
Great East - Site 3 Maine Mann
May 20, 2009
Temperature (°C)
0
5
10
15
20
25
30
0
4
8
12
Depth (meters)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Dissolved Oxygen (mg/l)
Temperature (°C)



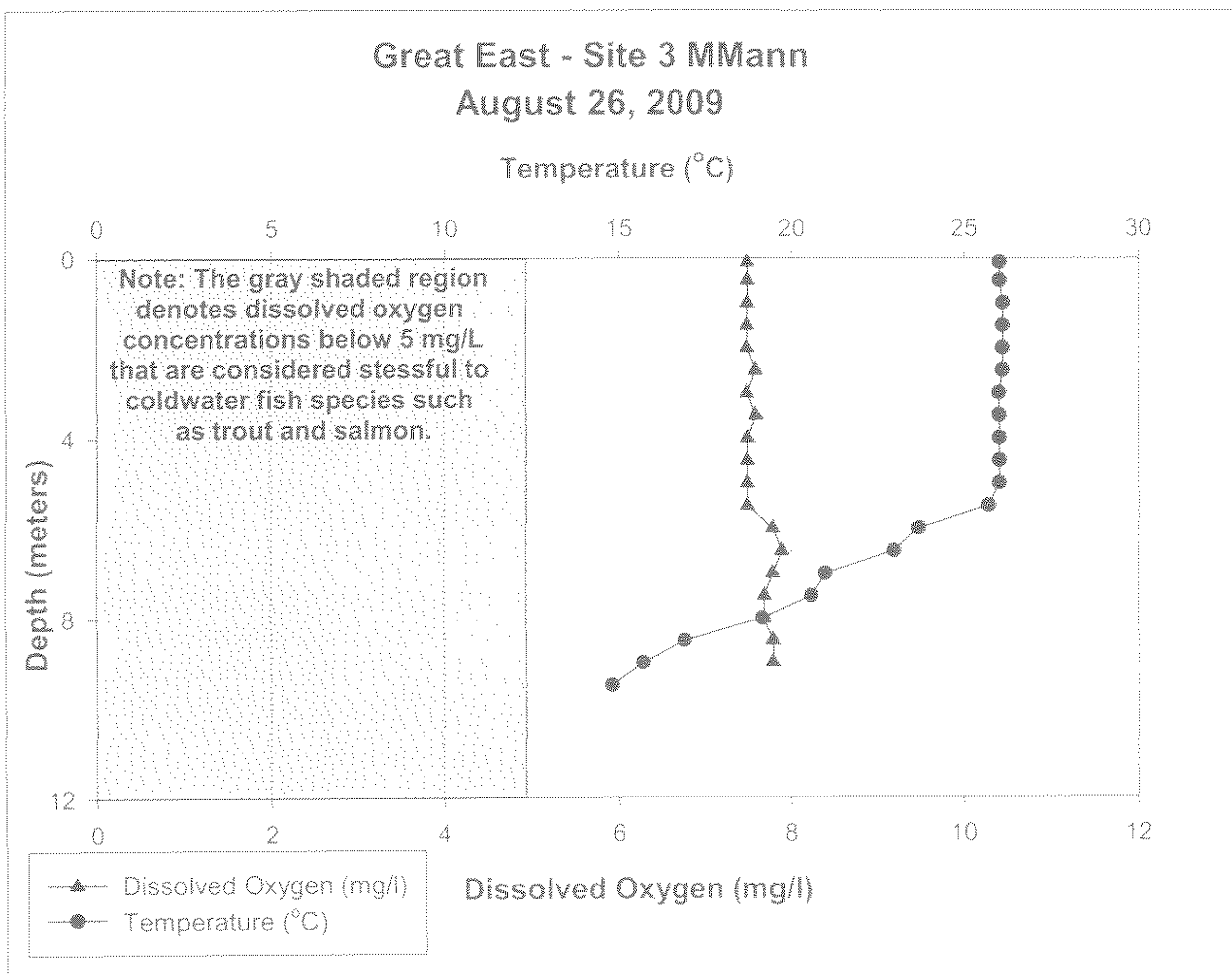
Great East - Site 3 MMann
June 8, 2009
Temperature (°C)
0
5
10
15
20
25
30
0
3
6
9
Depth (meters)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Dissolved Oxygen (mg/l)
Temperature (°C)


Great East - Site 3 MMann
July 1, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
4
8
12
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

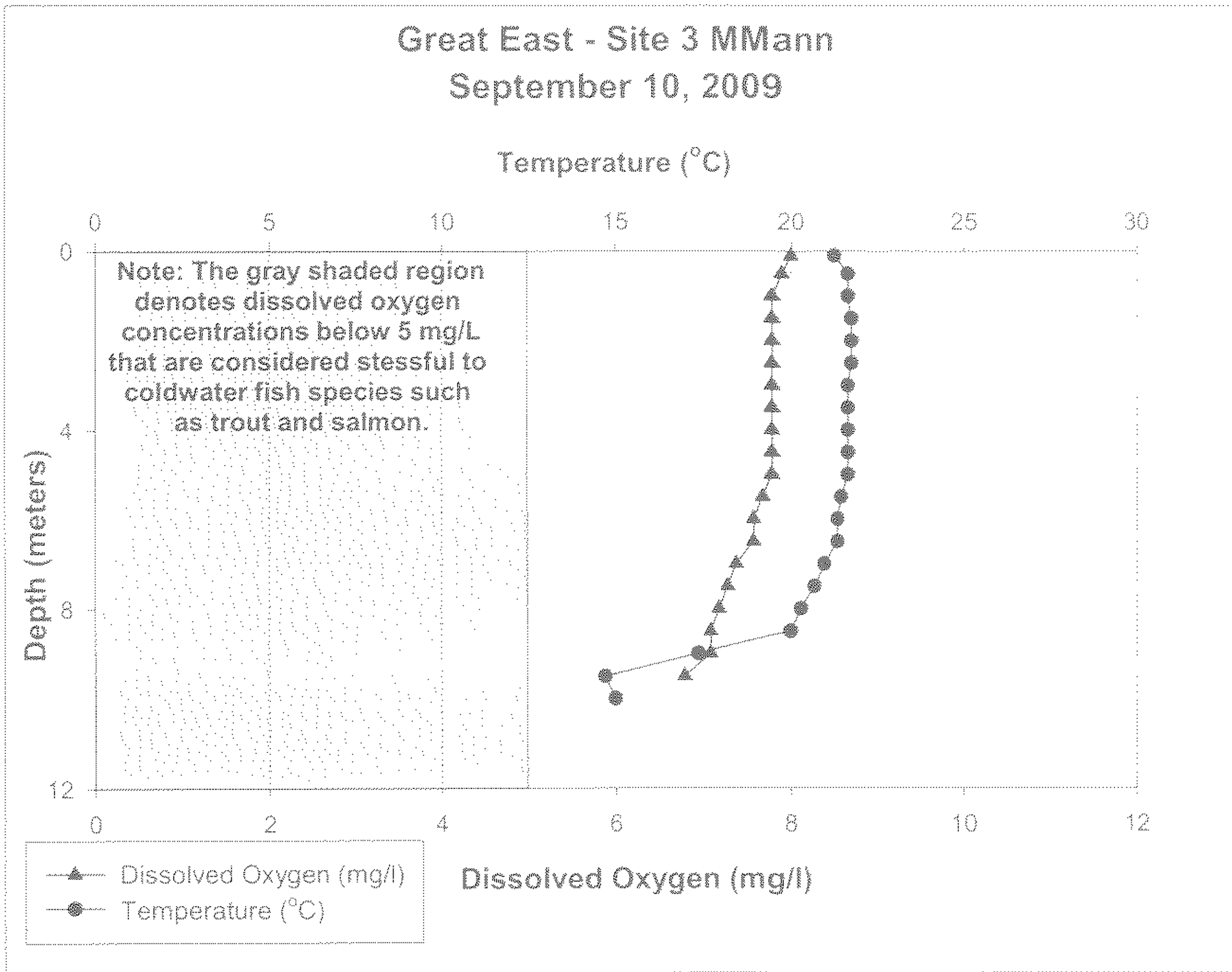

Great East - Site 3 MMann
July 16, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
4
8
12
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

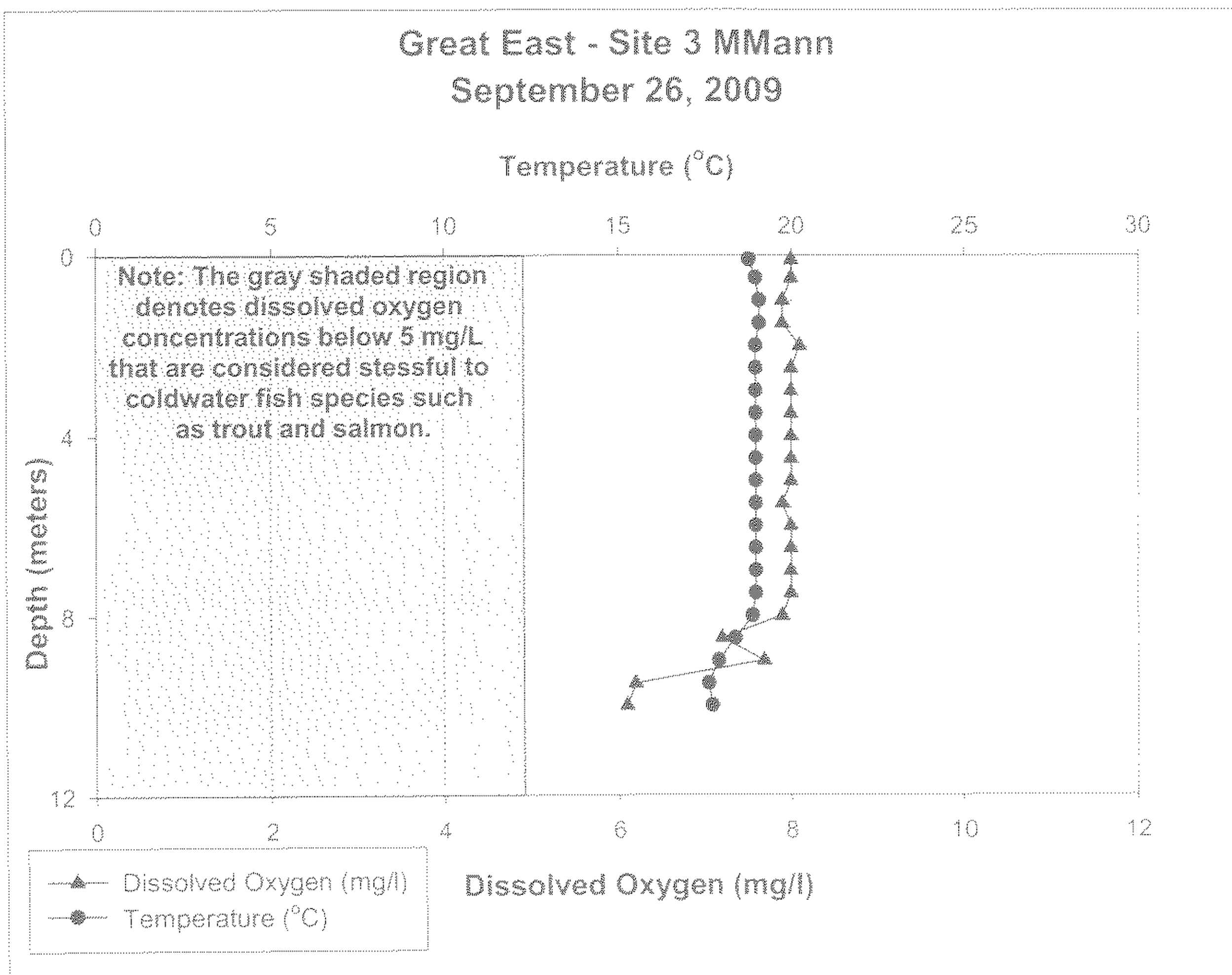


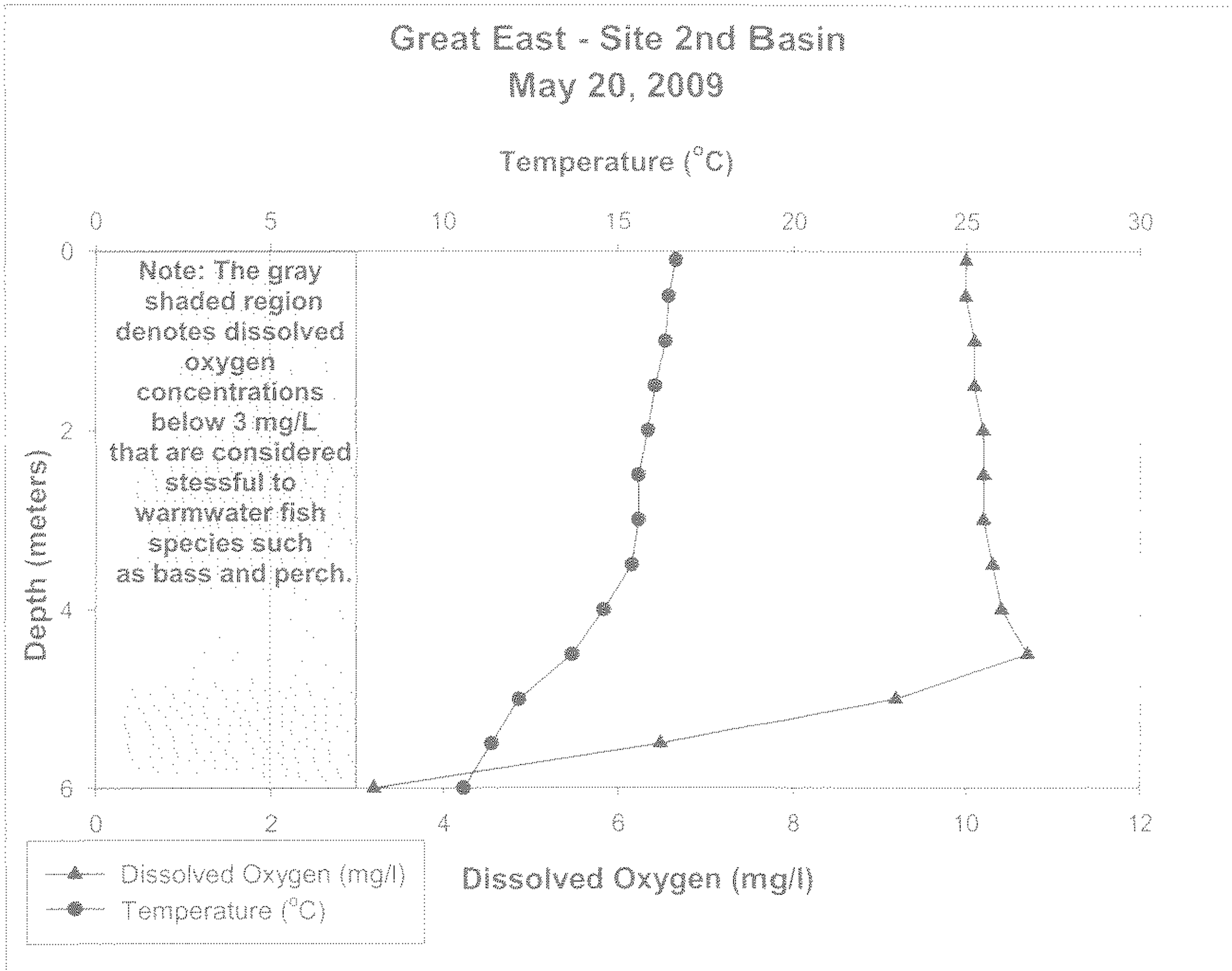
Great East - Site 3 MMann
August 3, 2009
Temperature (°C)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)



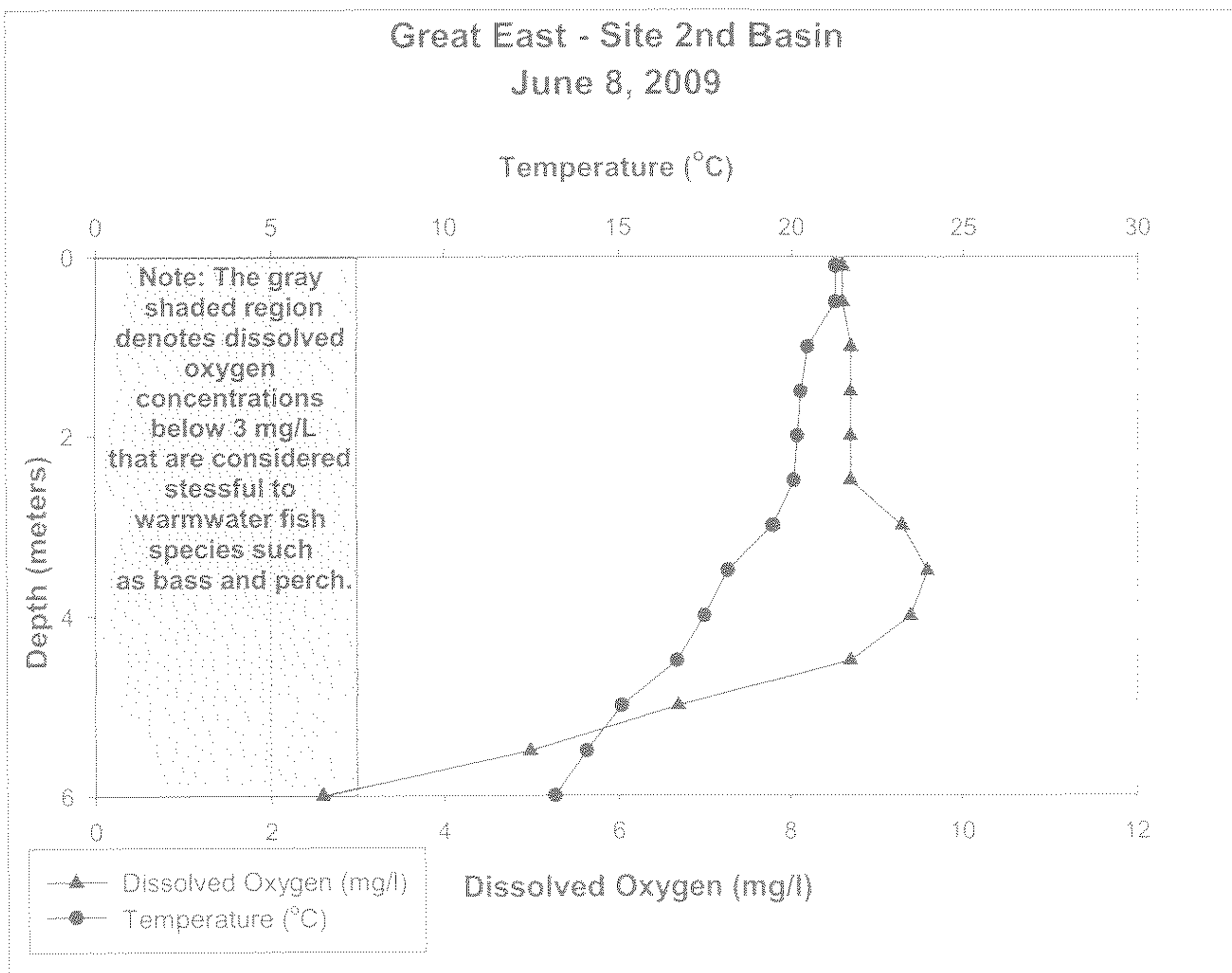
Great East - Site 3 MMann
August 26, 2009
Temperature (°C)
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)


Great East - Site 3 MMann
September 10, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
4
8
12
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

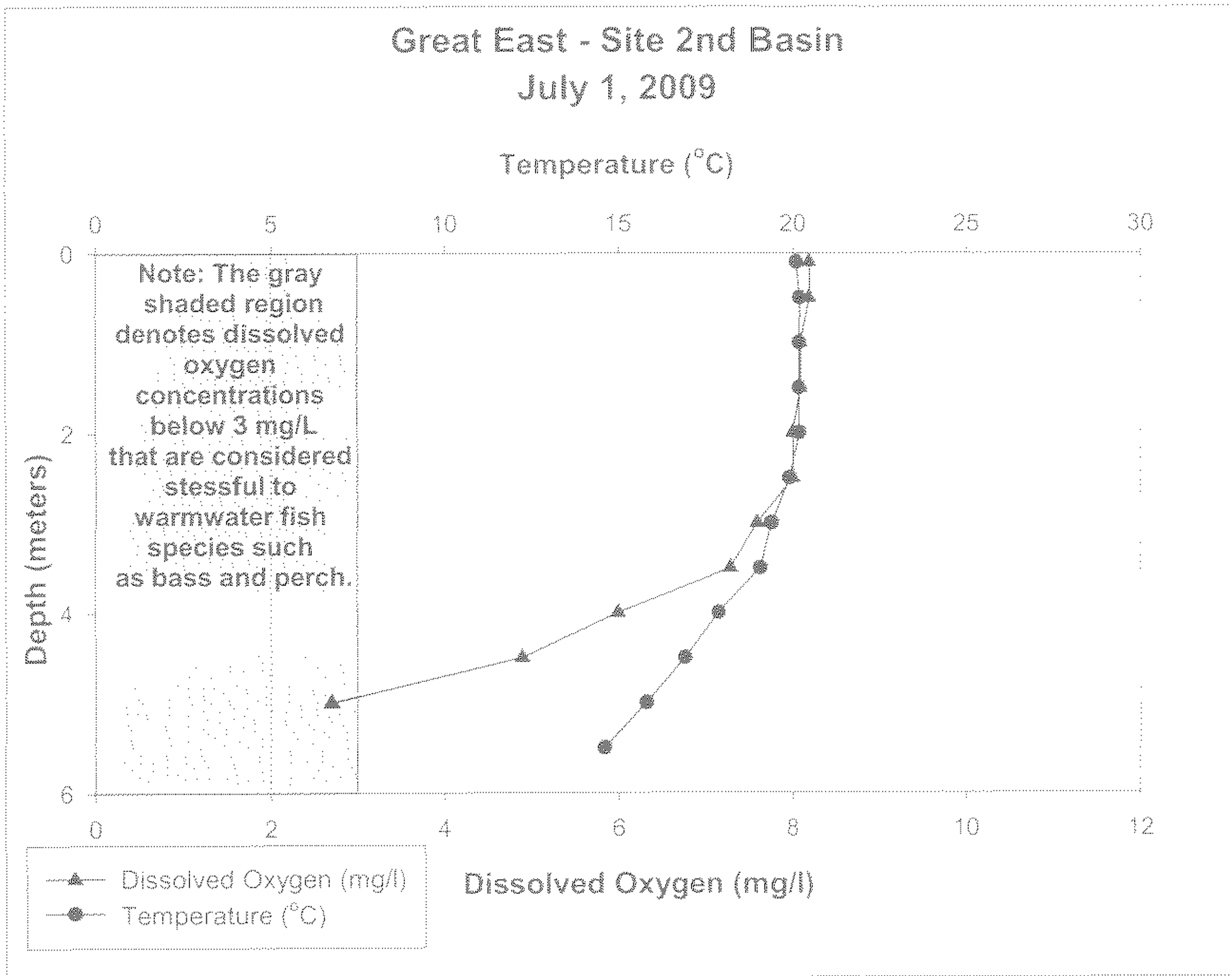

Great East - Site 3 MMann
September 26, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
4
8
12
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

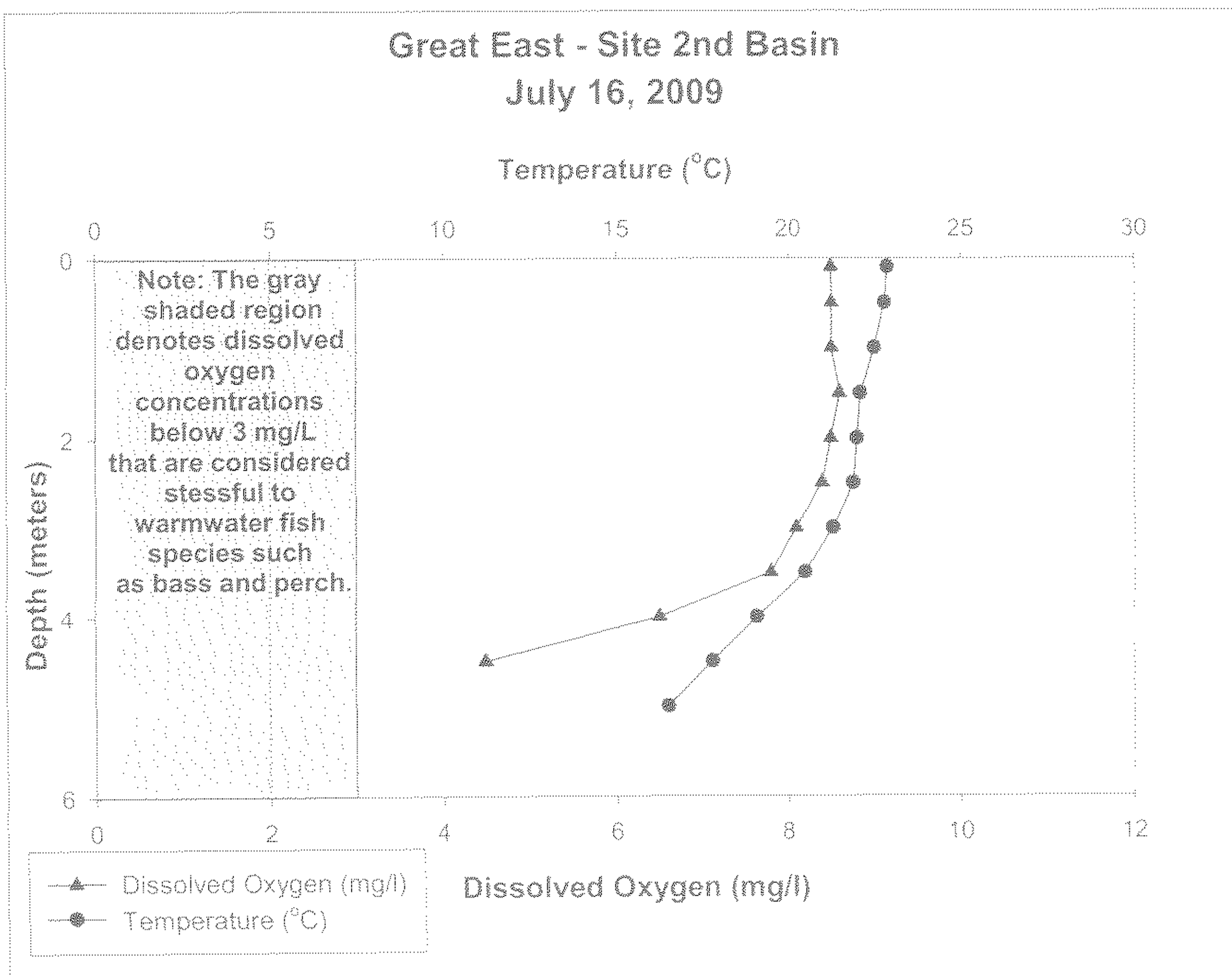


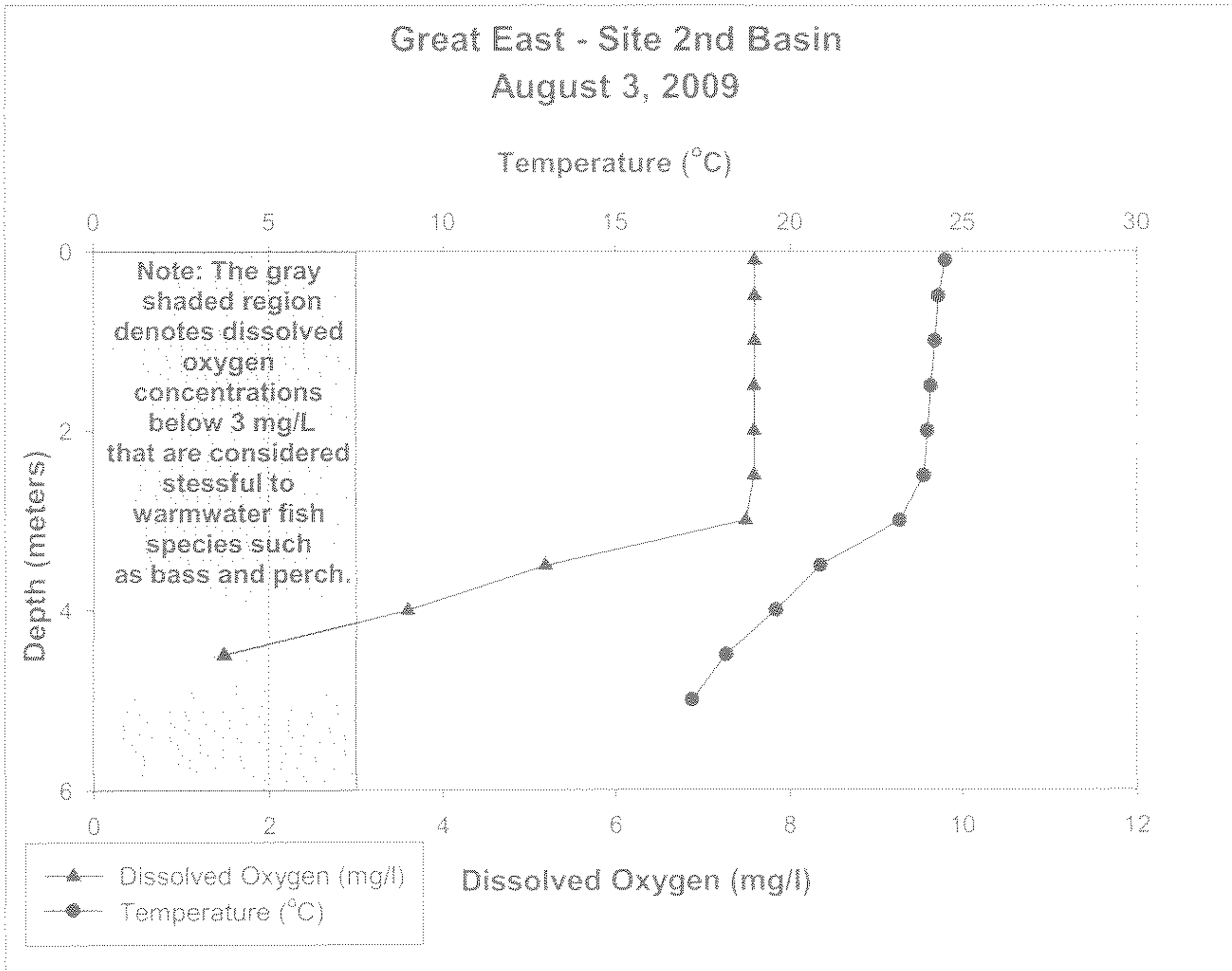
Great East - Site 2nd Basin
May 20, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 3 mg/L that are considered stessful to warmwater fish species such as bass and perch.
Depth (meters)
0
2
4
6
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

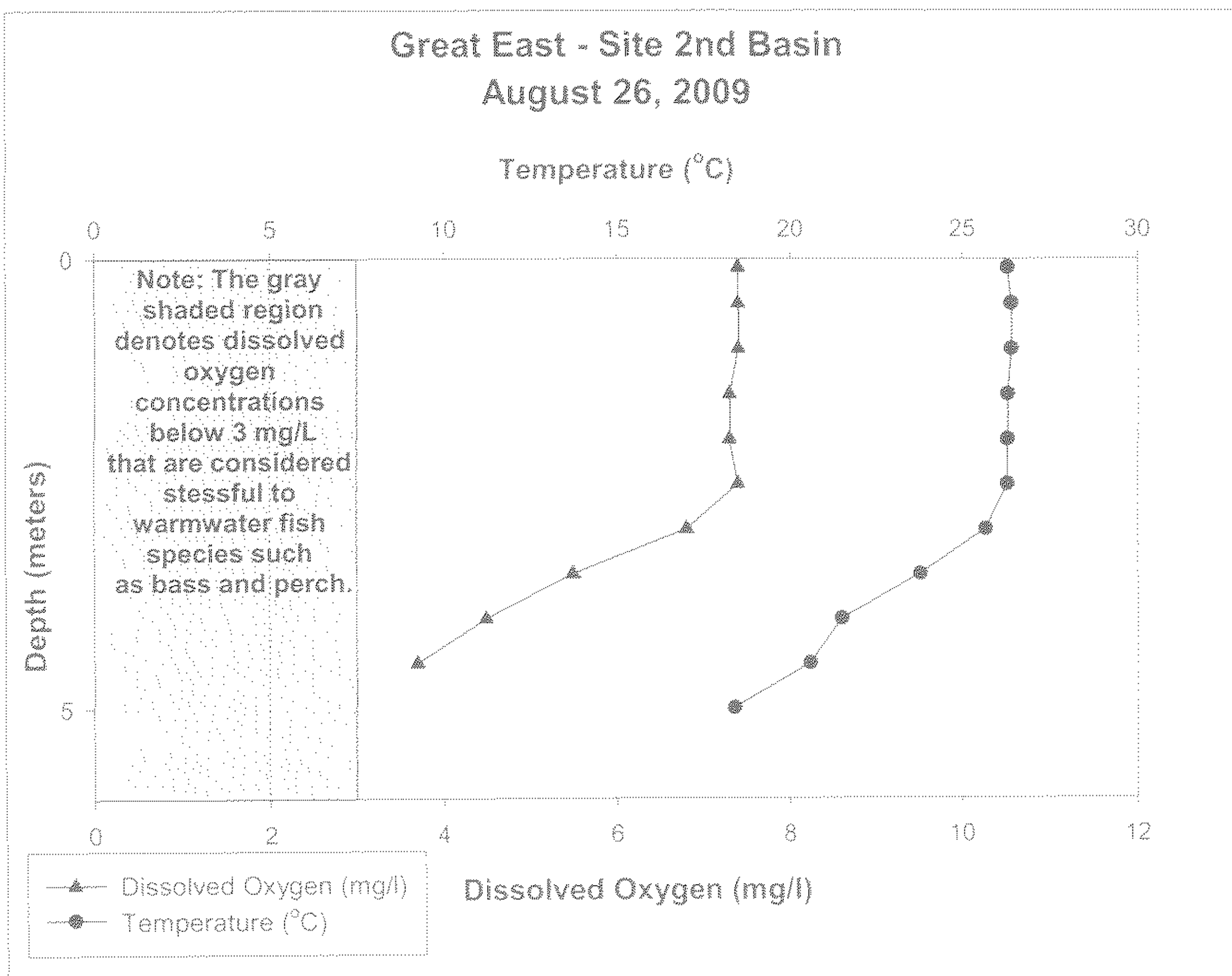


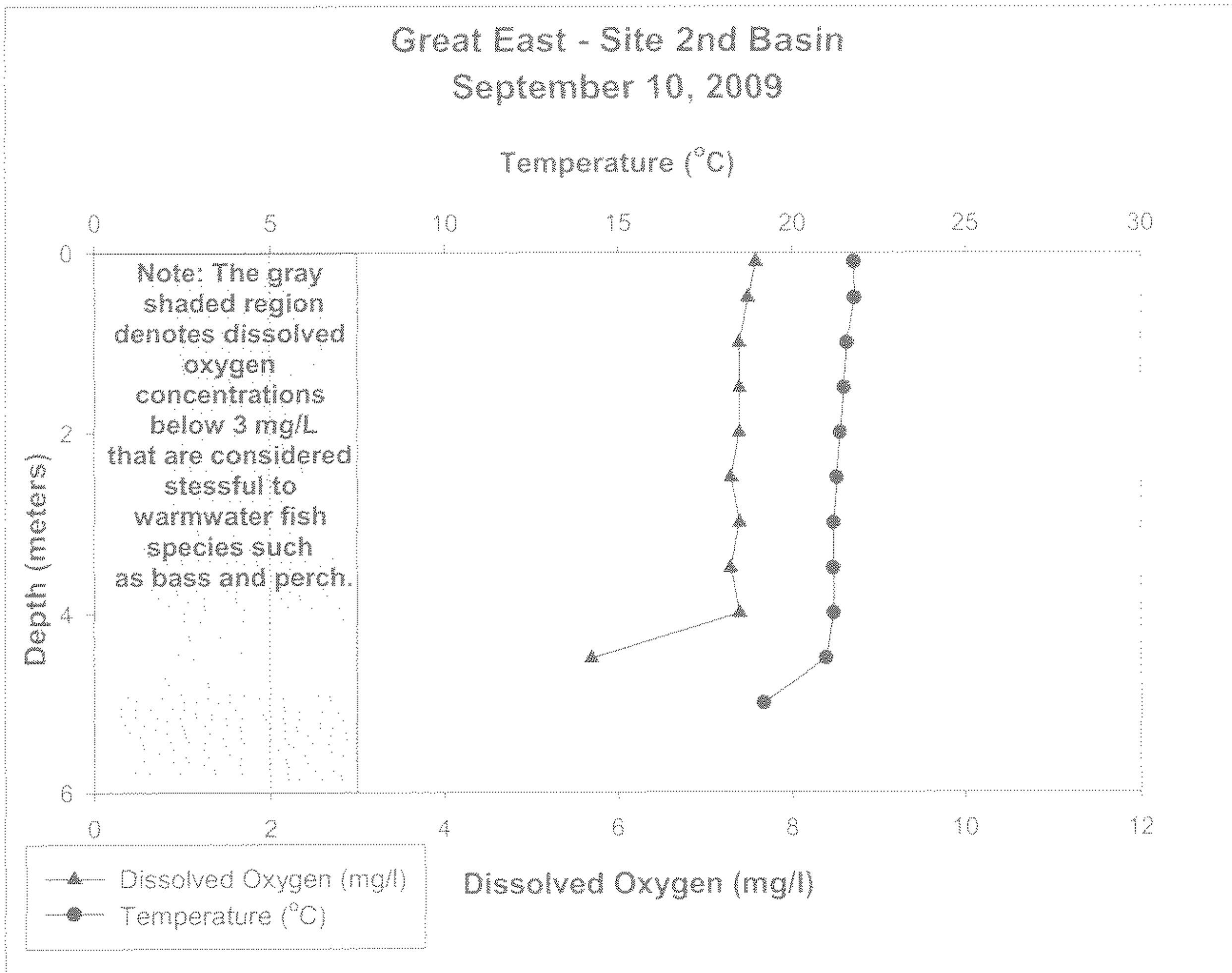
Great East - Site 2nd Basin
June 8, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 3 mg/L that are considered stessful to warmwater fish species such as bass and perch.
Depth (meters)
0
2
4
6
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)


Great East - Site 2nd Basin
July 1, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 3 mg/L that are considered stessful to warmwater fish species such as bass and perch.
Depth (meters)
0
2
4
6
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Dissolved Oxygen (mg/l)
Temperature (°C)

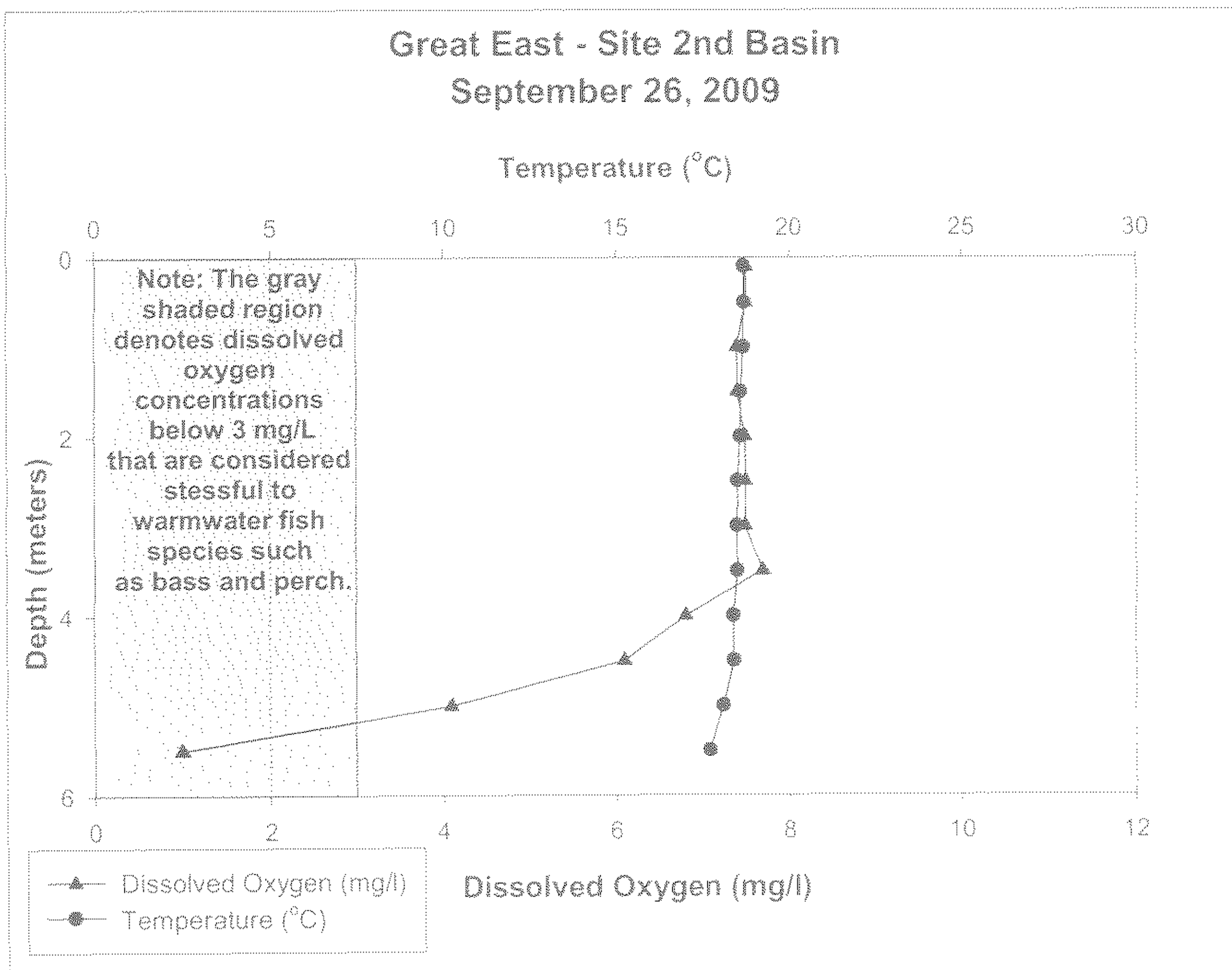

Great East - Site 2nd Basin
July 16, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 3 mg/L that are considered stessful to warmwater fish species such as bass and perch.
Depth (meters)
0
2
4
6
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Dissolved Oxygen (mg/l)
Temperature (°C)


Great East - Site 2nd Basin
August 3, 2009
Temperature (°C)
Depth (meters)
Note: The gray shaded region denotes dissolved oxygen concentrations below 3 mg/L that are considered stessful to warmwater fish species such as bass and perch.
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

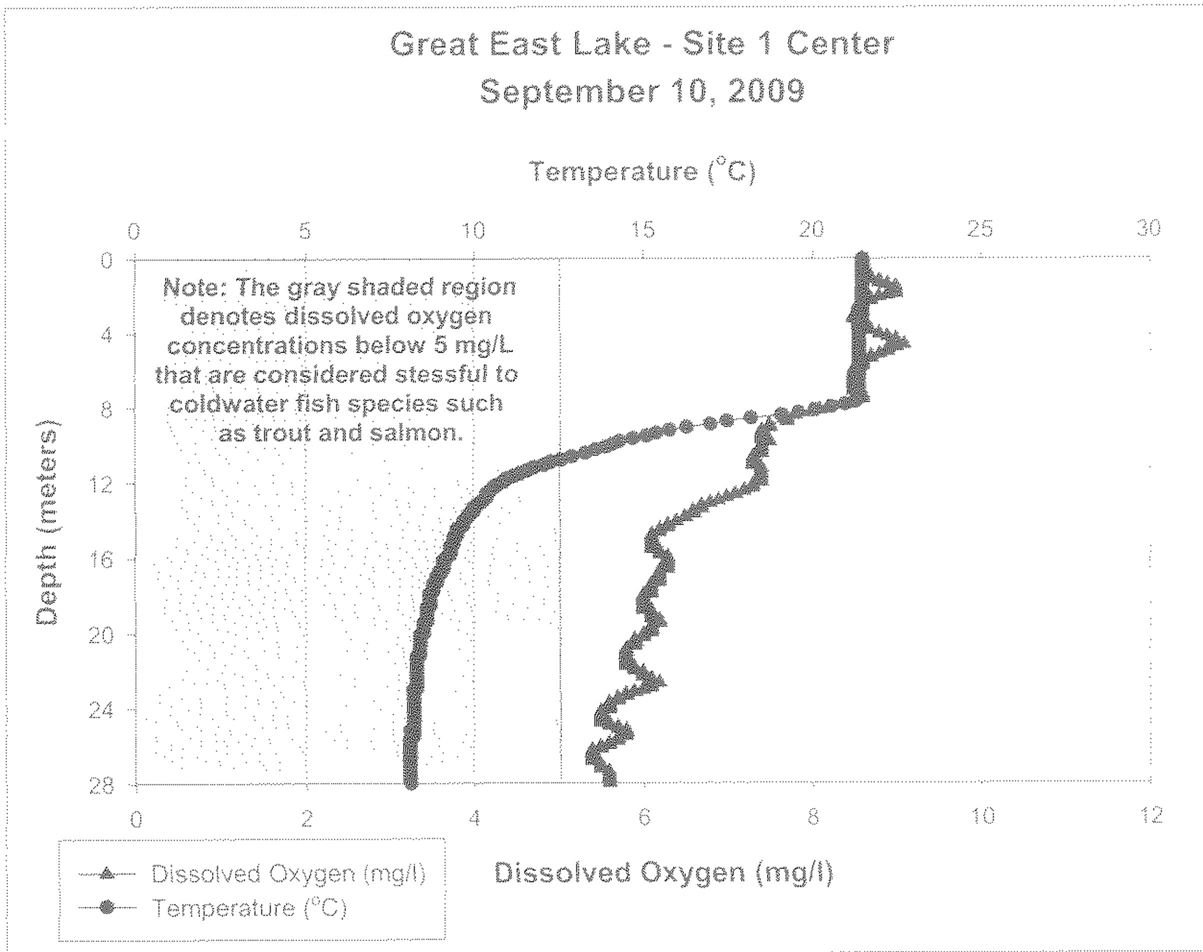

Great East - Site 2nd Basin
August 26, 2009
Temperature (°C)
Depth (meters)
Note: The gray shaded region denotes dissolved oxygen concentrations below 3 mg/L that are considered stessful to warmwater fish species such as bass and perch.
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

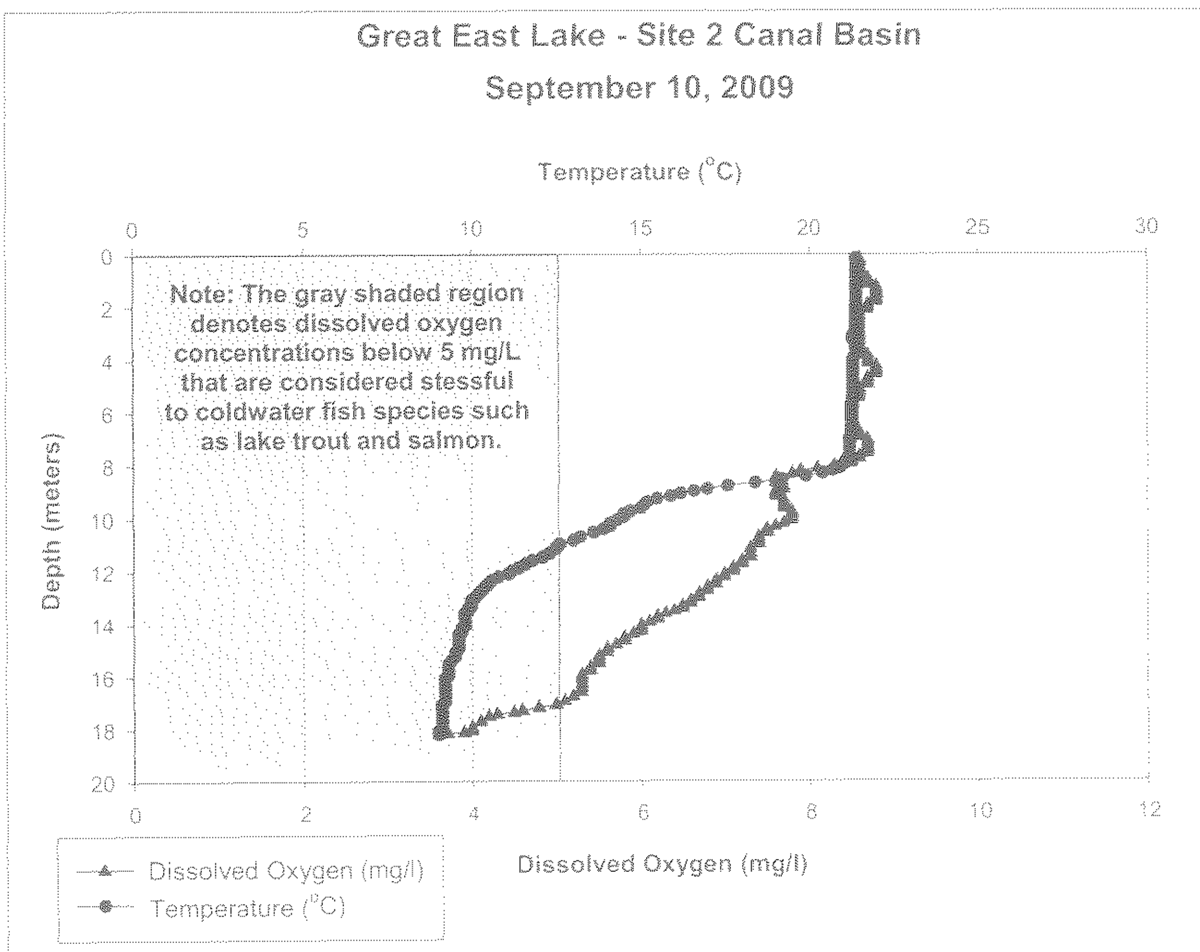


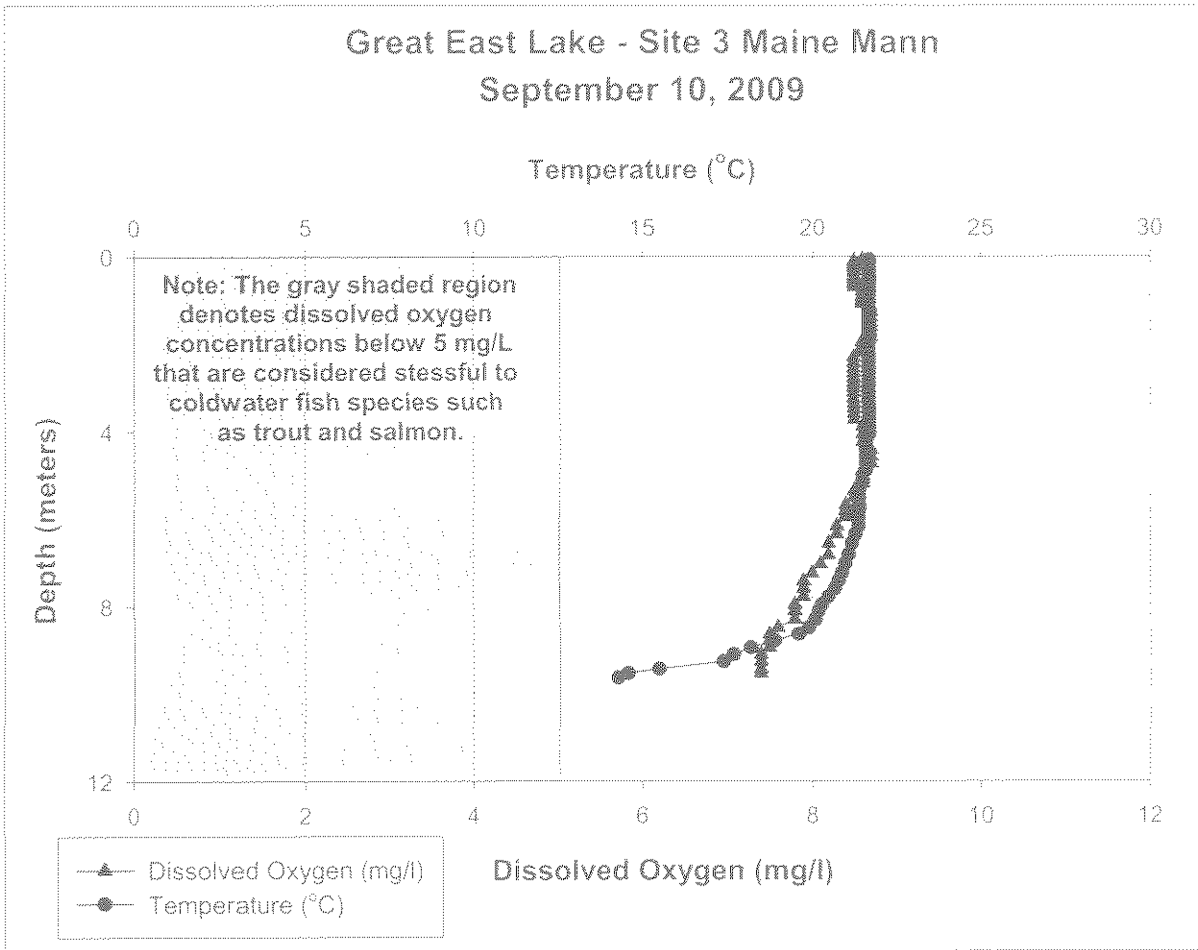
Great East - Site 2nd Basin
September 10, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 3 mg/L that are considered stessful to warmwater fish species such as bass and perch.
Depth (meters)
0
2
4
6
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)



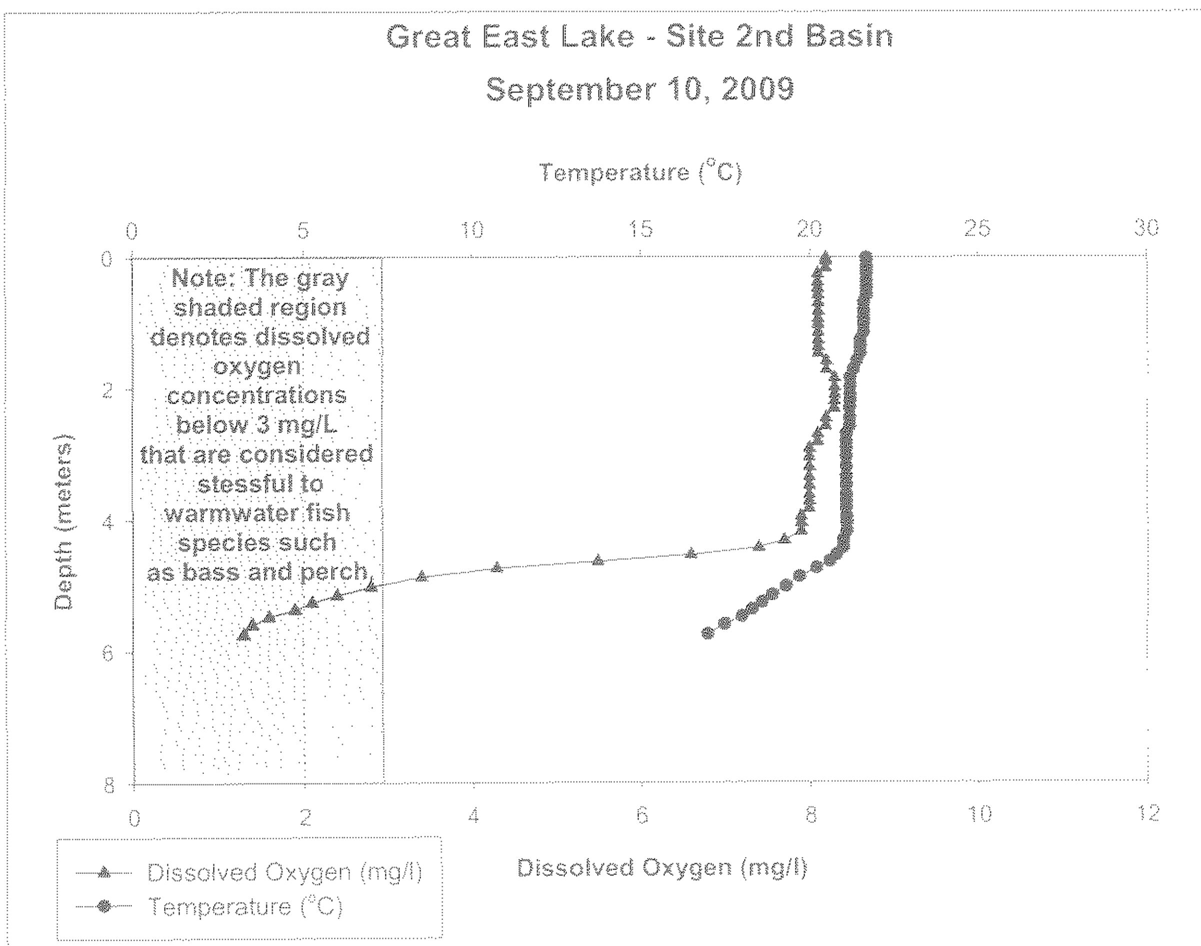
Great East - Site 2nd Basin
September 26, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 3 mg/L that are considered stessful to warmwater fish species such as bass and perch.
Depth (meters)
0
2
4
6
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)


Great East Lake - Site 1 Center
September 10, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
4
8
12
16
20
24
28
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)


Great East Lake - Site 2 Canal Basin
September 10, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as lake trout and salmon.
Depth (meters)
0
2
4
6
8
10
12
14
16
18
20
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)



Great East Lake - Site 3 Maine Mann
September 10, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as trout and salmon.
Depth (meters)
0
4
8
12
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)



Great East Lake - Site 2nd Basin
September 10, 2009
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 3 mg/L that are considered stessful to warmwater fish species such as bass and perch.
Depth (meters)
0
2
4
6
8
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

APPENDIX B

Lakes Lay Monitoring Program, U.N.H.
[Lay Monitor Data]

Great East Lake, Wakefield NH
-- subset of trophic indicators, all sites, 2009

Average transparency:	9.0 (2009:	31 values:	4.6	-	12.2 range)
Average chlorophyll:	1.5 (2009:	30 values:	0.6	-	4.4 range)
Average Color:	15.8 (2009:	28 values:	10.4	-	34.8 range)
Average Alkalinity (gray):	6.5 (2009:	31 values:	3.8	-	7.9 range)
Average Alkalinity (pink):	7.6 (2009:	31 values:	5.1	-	9.1 range)
Total phosphorus (ug/L):	8.2 (2009:	31 values:	4.0	-	15.6 range)

Site	Date	Secchi Disk Transparency (meters)	Chl *a* (ug/L)	Dissolved Color (CPU)	Alkalinity Gray end pt. @ pH 5.1 (mg/L)	Alkalinity pink end pt. @ pH 4.6 (mg/L)	Total Phosphorus (ug/L)
1 Center	5/20/2009	9.4	0.7	13.9	6.3	7.6	6.8
1 Center	6/8/2009	11.0	1.7	13.0	6.9	8.3	8.6
1 Center	7/1/2009	9.8	0.9	13.9	7.0	7.8	12.1
1 Center	7/16/2009	9.4	0.9	13.0	7.0	7.8	6.7
1 Center	8/3/2009	9.2	0.9	13.0	5.3	7.5	7.7
1 Center	8/26/2009	10.4	0.9	10.4	3.8	5.1	6.9
1 Center	9/10/2009	12.2	1.7	12.2	7.0	7.9	5.7
1 Center	9/26/2009	12.1	1.0	-----	7.0	8.3	4.0
2 Canal	6/8/2009	11.1	2.6	12.2	6.9	7.6	6.3
2 Canal	7/1/2009	9.5	1.3	14.8	6.9	7.5	7.2
2 Canal	7/16/2009	9.0	0.9	14.8	6.6	7.7	5.7
2 Canal	8/3/2009	10.3	0.9	12.2	4.1	5.4	6.6
2 Canal	8/26/2009	10.7	1.1	13.0	5.5	7.3	4.1
2 Canal	9/10/2009	10.8	1.4	10.4	7.0	8.0	4.9
2 Canal	9/26/2009	11.2	0.9	12.2	7.0	8.4	6.4
3 MMann	5/20/2009	10.5	0.8	-----	6.6	7.1	5.5
3 MMann	6/8/2009	9.9	1.0	12.2	7.8	8.1	13.2
3 MMann	7/1/2009	9.3	1.0	18.2	7.2	7.8	7.9
3 MMann	7/16/2009	9.7	0.9	13.9	7.3	7.9	11.9
3 MMann	8/3/2009	8.7	0.9	13.0	4.8	6.1	7.4
3 MMann	8/26/2009	9.5	1.1	12.2	6.2	7.0	4.7
3 MMann	9/10/2009	10.4	1.5	12.2	6.9	8.0	11.5
3 MMann	9/26/2009	10.0	-----	16.5	6.9	8.1	4.6
2nd Basin	5/20/2009	5.8	1.1	16.5	6.9	7.6	9.3
2nd Basin	6/8/2009	6.0	0.6	13.9	7.4	8.3	13.4
2nd Basin	7/1/2009	5.8	2.5	22.6	7.7	8.5	6.7
2nd Basin	7/16/2009	4.6	2.4	26.1	7.5	8.4	15.6
2nd Basin	8/3/2009	5.2	2.4	26.9	4.2	5.3	14.3
2nd Basin	8/26/2009	5.5	2.7	23.5	5.1	7.2	10.0

Site	Date	Secchi Disk Transparency (meters)	Chl *a* (µg/L)	Dissolved Color (CPU)	Alkalinity Gray end pt. @ pH 5.1 (mg/L)	Alkalinity pink end pt. @ pH 4.6 (mg/L)	Total Phosphorus (µg/L)
2nd Basin	8/26/2009	5.5	2.7	23.5	5.1	7.2	10.0
2nd Basin	9/10/2009	5.6	3.1	-----	7.9	9.1	10.1
2nd Basin	9/26/2009	5.3	4.4	34.8	7.4	8.4	9.4

<< End of 2009 data listing: 31 records >>

Lakes Lay Monitoring Program
[CFB Data – August 27, 2008]

Site	Depth (meters)	Chlorophyll (ug/l)	Alkalinity gray end @ pH 5.1 (mg/l)	Alkalinity pink end pt. @ pH 4.6 (mg/l)	Total Phosphorus (ug/l)
1 Center	0.5	1.7	7.2	7.8	-----
1 Center	10.0	2.5	7.0	7.5	5.8
1 Center	27.5	-----	6.5	7.1	6.2
1 Center	0-7.5	1.9	6.7	7.3	5.6
2 Canal	0.5	1.4	7.0	7.5	-----
2 Canal	10.0	2.6	6.9	7.4	4.3
2 Canal	17.0	-----	7.0	7.5	6.9
2 Canal	0-8.0	2.6	7.1	7.8	3.7
2nd Basin	0.5	3.4	8.0	8.5	-----
2nd Basin	5.0	6.3	9.0	9.6	13.9
2nd Basin	0-4.5	4.4	7.5	8.1	14.4
3 MainMann	0.5	2.5	6.3	7.4	-----
3 MainMann	2.5	-----	7.1	7.6	-----
3 MainMann	9.0	2.9	7.3	8.0	9.5
3 MainMann	0-7.0	1.9	7.6	8.1	14.2

Site	Secchi Disk Transparency (meters)
1 Center	11.1 meters
2 Canal	10.8 meters
3 MMann	9.8 meters

Site	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductivity @ 25°C (uS/cm)
1 Deep	0.03	21.5	8.6	97.1	60.0
1 Deep	0.12	21.5	8.6	97.1	60.0
1 Deep	0.16	21.5	8.6	97.1	60.0
1 Deep	0.24	21.5	8.6	97.0	60.0
1 Deep	0.33	21.5	8.6	96.9	60.0
1 Deep	0.41	21.5	8.6	96.9	60.0
1 Deep	0.50	21.5	8.6	96.9	60.0
1 Deep	0.58	21.5	8.6	96.9	60.0
1 Deep	0.64	21.5	8.6	96.9	60.0
1 Deep	0.71	21.5	8.6	96.8	60.0
1 Deep	0.80	21.5	8.6	96.9	60.0
1 Deep	0.90	21.5	8.6	97.2	60.0
1 Deep	0.99	21.5	8.7	97.9	60.0
1 Deep	1.09	21.5	8.7	98.6	60.0
1 Deep	1.19	21.5	8.8	99.2	60.0
1 Deep	1.27	21.5	8.8	100.0	60.0
1 Deep	1.37	21.5	8.9	100.7	60.0
1 Deep	1.48	21.5	9.0	101.5	60.0
1 Deep	1.58	21.5	9.0	102.4	60.0

Site	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductivity @ 25°C (uS/cm)
1 Deep	1.68	21.5	9.0	102.0	60.0
1 Deep	1.78	21.5	9.0	101.9	60.0
1 Deep	1.86	21.5	9.0	101.4	60.0
1 Deep	1.94	21.5	8.9	100.6	60.0
1 Deep	2.03	21.5	8.8	99.7	60.0
1 Deep	2.12	21.5	8.7	98.9	60.0
1 Deep	2.23	21.5	8.7	98.3	60.0
1 Deep	2.34	21.5	8.6	97.7	60.0
1 Deep	2.43	21.5	8.6	97.2	60.0
1 Deep	2.53	21.5	8.6	97.0	60.0
1 Deep	2.63	21.5	8.6	96.8	60.0
1 Deep	2.76	21.4	8.6	96.7	60.0
1 Deep	2.88	21.4	8.6	96.7	60.0
1 Deep	3.00	21.5	8.6	96.7	60.0
1 Deep	3.10	21.5	8.5	96.7	60.0
1 Deep	3.22	21.5	8.5	96.7	60.0
1 Deep	3.33	21.5	8.6	96.7	60.0
1 Deep	3.48	21.5	8.6	97.2	60.0
1 Deep	3.66	21.4	8.6	97.8	60.0
1 Deep	3.82	21.4	8.7	98.6	60.0
1 Deep	4.02	21.4	8.8	99.5	60.0
1 Deep	4.16	21.4	8.9	100.3	60.0
1 Deep	4.31	21.4	9.0	101.3	60.0
1 Deep	4.45	21.4	9.0	102.1	60.0
1 Deep	4.59	21.4	9.1	102.6	60.0
1 Deep	4.72	21.4	9.0	101.4	60.0
1 Deep	4.83	21.4	8.9	100.8	60.0
1 Deep	4.96	21.4	8.9	100.1	60.0
1 Deep	5.10	21.4	8.8	99.4	60.0
1 Deep	5.22	21.4	8.7	98.5	60.0
1 Deep	5.33	21.4	8.7	98.0	60.0
1 Deep	5.47	21.4	8.6	97.5	60.0
1 Deep	5.61	21.4	8.6	97.1	60.0
1 Deep	5.75	21.4	8.6	96.8	60.0
1 Deep	5.91	21.4	8.5	96.6	60.0
1 Deep	6.06	21.4	8.5	96.4	60.0
1 Deep	6.21	21.4	8.5	96.4	60.0
1 Deep	6.34	21.4	8.5	96.4	60.0
1 Deep	6.46	21.4	8.5	96.3	60.0
1 Deep	6.59	21.4	8.5	96.4	60.0
1 Deep	6.74	21.4	8.5	96.3	60.0
1 Deep	6.91	21.4	8.5	96.2	60.0
1 Deep	7.10	21.4	8.5	96.3	60.0
1 Deep	7.24	21.4	8.6	96.7	60.0
1 Deep	7.38	21.4	8.6	97.1	60.0
1 Deep	7.53	21.4	8.6	97.3	60.0

Site	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductivity @ 25°C (μS/cm)
1 Deep	7.68	21.3	8.5	95.9	60.0
1 Deep	7.82	21.0	8.4	93.6	60.0
1 Deep	7.96	20.6	8.2	91.5	60.0
1 Deep	8.11	20.1	8.1	89.4	60.0
1 Deep	8.25	19.6	8.0	87.2	60.0
1 Deep	8.39	19.1	7.8	84.1	60.0
1 Deep	8.56	18.2	7.7	81.7	59.0
1 Deep	8.72	17.5	7.7	80.1	60.0
1 Deep	8.89	17.0	7.5	77.8	60.0
1 Deep	9.06	16.3	7.5	76.2	60.0
1 Deep	9.22	15.8	7.4	75.1	60.0
1 Deep	9.37	15.4	7.4	74.0	60.0
1 Deep	9.52	15.1	7.4	73.3	60.0
1 Deep	9.67	14.7	7.4	72.9	60.0
1 Deep	9.81	14.3	7.5	72.8	60.0
1 Deep	9.96	14.1	7.4	72.3	60.0
1 Deep	10.11	13.9	7.4	71.6	60.0
1 Deep	10.25	13.6	7.4	71.2	60.0
1 Deep	10.43	13.3	7.4	70.3	60.0
1 Deep	10.62	12.9	7.3	69.4	60.0
1 Deep	10.78	12.6	7.3	68.8	60.0
1 Deep	10.91	12.3	7.3	68.2	60.0
1 Deep	11.07	12.1	7.3	67.9	60.0
1 Deep	11.21	11.8	7.4	67.9	60.0
1 Deep	11.37	11.6	7.4	67.8	60.0
1 Deep	11.53	11.4	7.4	67.5	60.0
1 Deep	11.67	11.2	7.4	67.2	60.0
1 Deep	11.82	11.0	7.4	66.8	60.0
1 Deep	11.97	10.9	7.4	66.5	60.0
1 Deep	12.15	10.7	7.3	66.0	60.0
1 Deep	12.29	10.6	7.3	65.4	60.0
1 Deep	12.45	10.5	7.2	64.6	60.0
1 Deep	12.61	10.4	7.1	63.7	60.0
1 Deep	12.78	10.4	7.0	62.5	61.0
1 Deep	12.95	10.3	6.9	61.3	60.0
1 Deep	13.08	10.2	6.8	60.5	60.0
1 Deep	13.22	10.1	6.7	59.8	60.0
1 Deep	13.37	10.0	6.7	59.2	61.0
1 Deep	13.51	10.0	6.6	58.7	61.0
1 Deep	13.66	9.9	6.6	58.3	60.0
1 Deep	13.84	9.8	6.5	57.6	60.0
1 Deep	14.07	9.7	6.4	56.5	60.0
1 Deep	14.24	9.7	6.3	55.6	61.0
1 Deep	14.37	9.6	6.3	54.9	61.0
1 Deep	14.49	9.5	6.2	54.5	61.0
1 Deep	14.64	9.5	6.2	54.0	61.0

Site	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductivity @ 25°C (uS/cm)
1 Deep	14.77	9.5	6.1	53.6	61.0
1 Deep	14.90	9.4	6.1	53.5	61.0
1 Deep	15.05	9.4	6.1	53.5	61.0
1 Deep	15.23	9.4	6.1	53.4	61.0
1 Deep	15.39	9.3	6.1	53.4	61.0
1 Deep	15.53	9.3	6.1	53.5	61.0
1 Deep	15.67	9.3	6.2	53.8	61.0
1 Deep	15.82	9.3	6.2	54.1	61.0
1 Deep	15.96	9.2	6.3	54.4	61.0
1 Deep	16.13	9.1	6.3	54.5	61.0
1 Deep	16.27	9.1	6.3	54.5	61.0
1 Deep	16.41	9.1	6.3	54.5	61.0
1 Deep	16.58	9.1	6.3	54.2	61.0
1 Deep	16.72	9.0	6.2	54.0	61.0
1 Deep	16.85	9.0	6.2	53.8	61.0
1 Deep	17.00	8.9	6.2	53.6	60.0
1 Deep	17.14	8.9	6.2	53.4	61.0
1 Deep	17.28	8.9	6.2	53.2	60.0
1 Deep	17.41	8.8	6.1	52.8	60.0
1 Deep	17.56	8.8	6.1	52.6	61.0
1 Deep	17.73	8.8	6.1	52.3	61.0
1 Deep	17.89	8.7	6.1	52.1	61.0
1 Deep	18.03	8.7	6.0	51.8	61.0
1 Deep	18.16	8.7	6.0	51.6	61.0
1 Deep	18.27	8.7	6.0	51.4	61.0
1 Deep	18.38	8.7	6.0	51.1	61.0
1 Deep	18.51	8.7	6.0	51.2	61.0
1 Deep	18.64	8.6	6.0	51.4	61.0
1 Deep	18.76	8.6	6.0	51.7	61.0
1 Deep	18.87	8.6	6.1	52.0	60.0
1 Deep	18.97	8.6	6.1	52.2	61.0
1 Deep	19.08	8.6	6.1	52.4	61.0
1 Deep	19.20	8.6	6.1	52.6	61.0
1 Deep	19.34	8.6	6.2	52.7	61.0
1 Deep	19.46	8.5	6.2	52.7	61.0
1 Deep	19.57	8.5	6.1	52.5	61.0
1 Deep	19.69	8.5	6.1	52.3	61.0
1 Deep	19.83	8.5	6.1	52.0	61.0
1 Deep	19.95	8.5	6.1	51.7	61.0
1 Deep	20.09	8.4	6.0	51.3	61.0
1 Deep	20.21	8.4	6.0	51.0	60.0
1 Deep	20.34	8.4	5.9	50.6	60.0
1 Deep	20.50	8.4	5.9	50.2	60.0
1 Deep	20.67	8.4	5.9	49.9	60.0
1 Deep	20.84	8.4	5.8	49.6	61.0
1 Deep	21.00	8.4	5.8	49.5	60.0

Site	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductivity @ 25°C (uS/cm)
1 Deep	21.14	8.4	5.8	49.5	61.0
1 Deep	21.25	8.3	5.8	49.5	60.0
1 Deep	21.38	8.3	5.8	49.5	61.0
1 Deep	21.50	8.3	5.8	49.5	60.0
1 Deep	21.62	8.3	5.8	49.5	60.0
1 Deep	21.74	8.3	5.8	49.7	61.0
1 Deep	21.86	8.3	5.9	50.0	61.0
1 Deep	21.98	8.3	5.9	50.3	60.0
1 Deep	22.08	8.3	6.0	50.7	60.0
1 Deep	22.20	8.3	6.0	50.9	60.0
1 Deep	22.32	8.3	6.0	51.3	60.0
1 Deep	22.45	8.3	6.1	51.8	60.0
1 Deep	22.54	8.3	6.1	52.2	60.0
1 Deep	22.64	8.3	6.2	52.4	60.0
1 Deep	22.77	8.3	6.1	52.2	61.0
1 Deep	22.90	8.3	6.1	51.7	61.0
1 Deep	23.02	8.2	6.0	51.0	61.0
1 Deep	23.14	8.2	5.9	50.2	61.0
1 Deep	23.24	8.2	5.8	49.6	61.0
1 Deep	23.35	8.2	5.8	49.1	61.0
1 Deep	23.47	8.2	5.7	48.6	61.0
1 Deep	23.59	8.2	5.7	48.2	61.0
1 Deep	23.71	8.2	5.6	47.8	61.0
1 Deep	23.84	8.2	5.6	47.5	61.0
1 Deep	23.96	8.2	5.6	47.3	61.0
1 Deep	24.07	8.2	5.6	47.2	61.0
1 Deep	24.16	8.2	5.5	47.0	61.0
1 Deep	24.28	8.2	5.5	46.8	61.0
1 Deep	24.40	8.2	5.5	46.8	61.0
1 Deep	24.51	8.2	5.5	46.6	61.0
1 Deep	24.60	8.2	5.5	46.5	61.0
1 Deep	24.68	8.2	5.5	46.7	61.0
1 Deep	24.77	8.2	5.5	47.0	61.0
1 Deep	24.86	8.2	5.6	47.3	61.0
1 Deep	24.94	8.2	5.6	47.8	61.0
1 Deep	25.02	8.2	5.7	48.2	61.0
1 Deep	25.10	8.2	5.7	48.5	61.0
1 Deep	25.18	8.1	5.8	48.8	61.0
1 Deep	25.25	8.2	5.8	49.1	61.0
1 Deep	25.31	8.2	5.8	49.2	61.0
1 Deep	25.39	8.2	5.8	49.1	61.0
1 Deep	25.49	8.2	5.8	48.8	61.0
1 Deep	25.60	8.1	5.7	48.4	61.0
1 Deep	25.74	8.1	5.7	47.9	61.0
1 Deep	25.89	8.1	5.6	47.5	61.0
1 Deep	25.98	8.1	5.6	47.1	61.0

Site	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductivity @ 25°C (μS/cm)
1 Deep	26.07	8.1	5.5	46.7	61.0
1 Deep	26.14	8.1	5.5	46.4	61.0
1 Deep	26.22	8.1	5.4	46.1	61.0
1 Deep	26.27	8.1	5.4	45.8	61.0
1 Deep	26.27	8.1	5.4	45.7	61.0
1 Deep	26.27	8.1	5.4	45.5	61.0
1 Deep	26.30	8.1	5.4	45.5	61.0
1 Deep	26.32	8.1	5.4	45.4	61.0
1 Deep	26.34	8.1	5.4	45.4	61.0
1 Deep	26.40	8.1	5.4	45.3	61.0
1 Deep	26.47	8.1	5.4	45.3	61.0
1 Deep	26.55	8.1	5.4	45.5	61.0
1 Deep	26.67	8.1	5.4	45.8	61.0
1 Deep	26.82	8.1	5.4	46.1	61.0
1 Deep	26.99	8.1	5.5	46.4	61.0
1 Deep	27.20	8.1	5.5	46.7	61.0
1 Deep	27.38	8.1	5.6	47.0	61.0
1 Deep	27.57	8.1	5.6	47.2	61.0
1 Deep	27.75	8.1	5.6	47.2	61.0
1 Deep	27.97	8.1	5.6	46.9	61.0
2 Canal	0.17	21.4	8.6	97.3	60.0
2 Canal	0.20	21.4	8.6	97.2	60.0
2 Canal	0.29	21.4	8.6	97.3	60.0
2 Canal	0.40	21.4	8.6	97.2	60.0
2 Canal	0.51	21.4	8.6	97.2	60.0
2 Canal	0.62	21.4	8.6	97.1	60.0
2 Canal	0.76	21.4	8.6	97.5	60.0
2 Canal	0.93	21.4	8.7	97.9	60.0
2 Canal	1.05	21.4	8.7	98.2	60.0
2 Canal	1.15	21.4	8.7	98.6	60.0
2 Canal	1.23	21.4	8.8	98.9	60.0
2 Canal	1.31	21.4	8.8	99.2	60.0
2 Canal	1.39	21.4	8.8	99.5	60.0
2 Canal	1.50	21.4	8.8	99.8	60.0
2 Canal	1.61	21.4	8.8	99.7	60.0
2 Canal	1.71	21.4	8.8	99.4	60.0
2 Canal	1.80	21.4	8.8	99.0	60.0
2 Canal	1.90	21.4	8.7	98.5	60.0
2 Canal	2.00	21.4	8.7	98.1	60.0
2 Canal	2.11	21.4	8.7	97.7	60.0
2 Canal	2.22	21.4	8.6	97.4	60.0
2 Canal	2.34	21.4	8.6	97.2	60.0
2 Canal	2.46	21.4	8.6	97.0	60.0
2 Canal	2.57	21.4	8.6	96.8	60.0
2 Canal	2.68	21.4	8.6	96.8	60.0
2 Canal	2.80	21.4	8.6	96.8	60.0

Site	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductivity @ 25°C (uS/cm)
2 Canal	2.90	21.4	8.6	96.7	60.0
2 Canal	3.01	21.4	8.6	96.7	60.0
2 Canal	3.12	21.3	8.6	96.7	60.0
2 Canal	3.23	21.3	8.6	96.6	60.0
2 Canal	3.34	21.4	8.6	96.6	60.0
2 Canal	3.47	21.4	8.6	96.8	60.0
2 Canal	3.60	21.4	8.6	97.1	60.0
2 Canal	3.72	21.4	8.6	97.4	60.0
2 Canal	3.84	21.4	8.7	97.8	60.0
2 Canal	3.99	21.3	8.7	98.2	60.0
2 Canal	4.13	21.3	8.7	98.5	60.0
2 Canal	4.25	21.3	8.8	98.8	60.0
2 Canal	4.36	21.3	8.8	99.0	60.0
2 Canal	4.46	21.3	8.8	99.1	60.0
2 Canal	4.56	21.3	8.8	98.9	60.0
2 Canal	4.69	21.3	8.7	98.6	60.0
2 Canal	4.82	21.3	8.7	98.1	60.0
2 Canal	4.94	21.3	8.7	97.7	60.0
2 Canal	5.09	21.3	8.6	97.3	60.0
2 Canal	5.23	21.3	8.6	97.0	60.0
2 Canal	5.35	21.3	8.6	96.7	60.0
2 Canal	5.45	21.3	8.6	96.5	60.0
2 Canal	5.55	21.3	8.5	96.3	60.0
2 Canal	5.65	21.3	8.5	96.3	60.0
2 Canal	5.78	21.3	8.5	96.3	60.0
2 Canal	5.89	21.3	8.5	96.2	60.0
2 Canal	5.98	21.3	8.5	96.1	60.0
2 Canal	6.09	21.3	8.5	96.1	60.0
2 Canal	6.21	21.3	8.5	96.1	60.0
2 Canal	6.39	21.3	8.5	95.9	60.0
2 Canal	6.52	21.3	8.5	96.0	60.0
2 Canal	6.64	21.3	8.5	96.3	60.0
2 Canal	6.75	21.3	8.6	96.6	60.0
2 Canal	6.84	21.3	8.6	97.0	60.0
2 Canal	6.94	21.3	8.6	97.3	60.0
2 Canal	7.03	21.2	8.7	97.5	60.0
2 Canal	7.13	21.2	8.7	97.7	60.0
2 Canal	7.24	21.2	8.7	98.0	60.0
2 Canal	7.35	21.2	8.7	98.1	60.0
2 Canal	7.45	21.2	8.7	97.9	60.0
2 Canal	7.56	21.2	8.7	97.7	60.0
2 Canal	7.66	21.2	8.6	97.2	60.0
2 Canal	7.76	21.2	8.6	96.7	60.0
2 Canal	7.84	21.1	8.5	96.1	60.0
2 Canal	7.94	21.1	8.5	95.0	60.0
2 Canal	8.03	21.0	8.3	92.7	60.0

Site	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductivity @ 25°C (uS/cm)
2 Canal	8.13	20.9	8.1	90.3	60.0
2 Canal	8.22	20.7	7.9	88.0	60.0
2 Canal	8.32	20.4	7.8	85.9	60.0
2 Canal	8.43	19.9	7.6	83.6	60.0
2 Canal	8.55	19.2	7.6	81.9	60.0
2 Canal	8.68	18.4	7.6	81.0	60.0
2 Canal	8.79	17.6	7.7	80.6	60.0
2 Canal	8.91	17.0	7.7	80.0	60.0
2 Canal	8.99	16.6	7.6	78.2	60.0
2 Canal	9.08	16.2	7.6	77.1	60.0
2 Canal	9.18	15.9	7.6	76.8	60.0
2 Canal	9.28	15.5	7.7	77.0	60.0
2 Canal	9.40	15.2	7.7	76.8	61.0
2 Canal	9.51	15.1	7.7	76.6	61.0
2 Canal	9.63	15.0	7.7	76.5	61.0
2 Canal	9.75	14.7	7.8	76.8	60.0
2 Canal	9.85	14.5	7.8	76.6	60.0
2 Canal	9.96	14.5	7.8	76.2	60.0
2 Canal	10.08	14.3	7.8	75.8	60.0
2 Canal	10.20	14.1	7.7	74.9	60.0
2 Canal	10.31	14.1	7.6	73.7	60.0
2 Canal	10.42	13.9	7.5	72.6	60.0
2 Canal	10.55	13.6	7.5	71.7	60.0
2 Canal	10.71	13.2	7.4	70.9	60.0
2 Canal	10.85	13.0	7.4	70.2	60.0
2 Canal	10.99	12.6	7.4	69.6	60.0
2 Canal	11.14	12.5	7.3	68.6	61.0
2 Canal	11.34	12.3	7.3	68.1	60.0
2 Canal	11.48	12.1	7.3	67.6	61.0
2 Canal	11.61	11.8	7.2	66.8	61.0
2 Canal	11.73	11.6	7.2	65.9	61.0
2 Canal	11.88	11.4	7.1	65.2	61.0
2 Canal	12.00	11.2	7.1	64.4	61.0
2 Canal	12.11	11.1	7.0	63.6	60.0
2 Canal	12.22	10.8	7.0	62.9	61.0
2 Canal	12.35	10.6	6.9	62.2	60.0
2 Canal	12.49	10.5	6.9	61.5	60.0
2 Canal	12.61	10.4	6.8	60.8	61.0
2 Canal	12.74	10.3	6.8	60.2	60.0
2 Canal	12.86	10.2	6.7	59.7	61.0
2 Canal	13.00	10.1	6.7	59.2	61.0
2 Canal	13.11	10.0	6.6	58.7	61.0
2 Canal	13.22	10.0	6.6	58.2	61.0
2 Canal	13.32	10.0	6.5	57.7	61.0
2 Canal	13.42	9.9	6.5	57.0	61.0
2 Canal	13.51	9.9	6.4	56.4	61.0

Site	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductivity @ 25°C (µS/cm)
2 Canal	13.60	9.8	6.3	55.7	61.0
2 Canal	13.72	9.8	6.2	55.0	61.0
2 Canal	13.82	9.8	6.2	54.4	61.0
2 Canal	13.93	9.8	6.1	53.8	61.0
2 Canal	14.05	9.8	6.0	53.3	61.0
2 Canal	14.16	9.7	6.0	52.8	61.0
2 Canal	14.28	9.7	6.0	52.3	61.0
2 Canal	14.39	9.6	5.9	51.8	61.0
2 Canal	14.51	9.6	5.8	51.2	61.0
2 Canal	14.65	9.6	5.8	50.6	61.0
2 Canal	14.79	9.6	5.7	50.1	61.0
2 Canal	14.92	9.6	5.6	49.5	61.0
2 Canal	15.07	9.5	5.6	48.7	61.0
2 Canal	15.21	9.5	5.5	48.3	61.0
2 Canal	15.36	9.4	5.5	48.0	61.0
2 Canal	15.50	9.3	5.5	47.7	61.0
2 Canal	15.65	9.3	5.4	47.3	61.0
2 Canal	15.78	9.3	5.4	46.8	61.0
2 Canal	15.94	9.3	5.3	46.3	61.0
2 Canal	16.08	9.2	5.3	46.0	61.0
2 Canal	16.26	9.2	5.3	46.0	61.0
2 Canal	16.42	9.2	5.3	46.0	61.0
2 Canal	16.59	9.2	5.3	45.6	61.0
2 Canal	16.77	9.2	5.2	45.1	61.0
2 Canal	16.94	9.2	5.1	44.4	61.0
2 Canal	17.09	9.1	5.0	43.1	61.0
2 Canal	17.19	9.1	4.8	41.5	61.0
2 Canal	17.30	9.1	4.6	40.0	61.0
2 Canal	17.38	9.1	4.5	38.7	61.0
2 Canal	17.43	9.1	4.3	37.5	61.0
2 Canal	17.53	9.1	4.2	36.7	61.0
2 Canal	17.72	9.1	4.1	35.7	62.0
2 Canal	17.93	9.1	4.0	35.0	62.0
2 Canal	18.07	9.0	4.0	34.2	62.0
2 Canal	18.13	9.0	3.9	33.3	62.0
2 Canal	18.16	9.0	3.7	32.4	62.0
2 Canal	18.20	9.0	3.6	30.7	62.0
3 Maine Mann	0.08	21.7	8.6	98.0	60.0
3 Maine Mann	0.10	21.7	8.6	97.3	60.0
3 Maine Mann	0.17	21.7	8.5	97.1	60.0
3 Maine Mann	0.24	21.7	8.5	97.0	60.0
3 Maine Mann	0.33	21.7	8.5	97.0	60.0
3 Maine Mann	0.43	21.7	8.5	97.0	60.0
3 Maine Mann	0.49	21.7	8.5	97.0	60.0
3 Maine Mann	0.55	21.7	8.5	96.9	60.0

Site	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductivity @ 25°C (μS/cm)
3 Maine Mann	0.62	21.7	8.5	96.8	60.0
3 Maine Mann	0.69	21.7	8.5	96.8	60.0
3 Maine Mann	0.79	21.7	8.5	96.9	60.0
3 Maine Mann	0.92	21.7	8.6	97.2	60.0
3 Maine Mann	1.01	21.7	8.6	97.6	60.0
3 Maine Mann	1.08	21.7	8.6	98.0	60.0
3 Maine Mann	1.17	21.7	8.6	98.3	60.0
3 Maine Mann	1.27	21.7	8.7	98.7	60.0
3 Maine Mann	1.39	21.7	8.7	98.9	60.0
3 Maine Mann	1.51	21.7	8.7	99.2	60.0
3 Maine Mann	1.61	21.7	8.7	99.4	60.0
3 Maine Mann	1.72	21.7	8.7	99.2	60.0
3 Maine Mann	1.83	21.7	8.7	99.0	60.0
3 Maine Mann	1.96	21.7	8.7	98.5	60.0
3 Maine Mann	2.08	21.7	8.6	98.1	60.0
3 Maine Mann	2.19	21.7	8.6	97.8	60.0
3 Maine Mann	2.31	21.7	8.6	97.4	60.0
3 Maine Mann	2.44	21.7	8.5	97.1	60.0
3 Maine Mann	2.56	21.7	8.5	96.9	60.0
3 Maine Mann	2.67	21.7	8.5	96.8	60.0
3 Maine Mann	2.79	21.7	8.5	96.8	60.0
3 Maine Mann	2.90	21.7	8.5	96.6	60.0
3 Maine Mann	3.00	21.7	8.5	96.6	60.0
3 Maine Mann	3.11	21.7	8.5	96.5	60.0
3 Maine Mann	3.25	21.7	8.5	96.5	60.0
3 Maine Mann	3.36	21.7	8.5	96.4	60.0
3 Maine Mann	3.47	21.7	8.5	96.3	60.0
3 Maine Mann	3.59	21.7	8.5	96.3	60.0
3 Maine Mann	3.73	21.7	8.5	96.6	60.0
3 Maine Mann	3.88	21.7	8.5	96.9	60.0
3 Maine Mann	4.06	21.7	8.6	97.2	60.0
3 Maine Mann	4.24	21.6	8.6	97.5	60.0
3 Maine Mann	5.01	21.5	8.6	97.9	60.0
3 Maine Mann	5.17	21.5	8.6	97.5	60.0
3 Maine Mann	5.34	21.4	8.6	97.0	60.0
3 Maine Mann	5.50	21.4	8.5	96.4	60.0
3 Maine Mann	5.67	21.4	8.5	95.8	60.0
3 Maine Mann	5.81	21.4	8.4	95.3	60.0
3 Maine Mann	5.95	21.4	8.4	94.8	60.0
3 Maine Mann	6.15	21.4	8.4	94.4	60.0
3 Maine Mann	6.34	21.3	8.3	93.8	60.0
3 Maine Mann	6.55	21.2	8.3	93.2	60.0
3 Maine Mann	6.81	21.1	8.2	92.7	60.0
3 Maine Mann	7.02	21.0	8.2	91.9	60.0
3 Maine Mann	7.23	20.9	8.1	90.9	60.0

Site	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductivity @ 25°C (μS/cm)
3 Maine Mann	7.41	20.8	8.0	89.4	60.0
3 Maine Mann	7.58	20.7	7.9	88.4	60.0
3 Maine Mann	7.77	20.5	7.9	87.6	60.0
3 Maine Mann	7.95	20.3	7.9	86.9	60.0
3 Maine Mann	8.10	20.2	7.8	86.5	60.0
3 Maine Mann	8.29	20.1	7.8	86.2	60.0
3 Maine Mann	8.48	19.9	7.8	85.4	60.0
3 Maine Mann	8.63	19.6	7.6	83.1	60.0
3 Maine Mann	8.78	18.9	7.5	80.8	60.0
3 Maine Mann	8.94	18.2	7.5	79.7	61.0
3 Maine Mann	9.10	17.7	7.5	78.9	61.0
3 Maine Mann	9.26	17.4	7.4	76.9	60.0
3 Maine Mann	9.43	15.5	7.4	74.4	61.0
3 Maine Mann	9.53	14.6	7.4	73.2	62.0
3 Maine Mann	9.63	14.3	7.4	72.2	62.0
2nd Basin	0.02	21.7	8.2	93.8	57.0
2nd Basin	0.06	21.7	8.2	93.1	57.0
2nd Basin	0.17	21.7	8.2	92.8	57.0
2nd Basin	0.26	21.7	8.1	92.5	57.0
2nd Basin	0.38	21.7	8.1	92.2	57.0
2nd Basin	0.48	21.7	8.1	92.1	57.0
2nd Basin	0.58	21.7	8.1	92.0	57.0
2nd Basin	0.70	21.6	8.1	92.0	57.0
2nd Basin	0.83	21.6	8.1	92.0	57.0
2nd Basin	0.94	21.6	8.1	91.8	57.0
2nd Basin	1.03	21.6	8.1	91.7	57.0
2nd Basin	1.15	21.6	8.1	91.6	57.0
2nd Basin	1.27	21.5	8.1	91.8	57.0
2nd Basin	1.37	21.5	8.1	92.0	57.0
2nd Basin	1.47	21.5	8.1	92.2	57.0
2nd Basin	1.59	21.4	8.2	92.5	57.0
2nd Basin	1.72	21.3	8.2	92.8	57.0
2nd Basin	1.85	21.2	8.3	93.3	57.0
2nd Basin	1.99	21.2	8.3	93.6	57.0
2nd Basin	2.10	21.2	8.3	93.6	57.0
2nd Basin	2.20	21.2	8.3	93.3	57.0
2nd Basin	2.31	21.2	8.3	92.9	57.0
2nd Basin	2.46	21.2	8.2	92.3	57.0
2nd Basin	2.58	21.2	8.2	91.7	57.0
2nd Basin	2.70	21.1	8.1	91.1	57.0
2nd Basin	2.82	21.1	8.1	90.6	57.0
2nd Basin	2.92	21.1	8.0	90.2	57.0
2nd Basin	3.05	21.1	8.0	90.0	57.0
2nd Basin	3.20	21.1	8.0	89.7	57.0
2nd Basin	3.35	21.1	8.0	89.6	57.0

Site	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (% saturation)	Specific Conductivity @ 25°C (uS/cm)
2nd Basin	3.48	21.1	8.0	89.6	57.0
2nd Basin	3.62	21.1	8.0	89.5	57.0
2nd Basin	3.72	21.1	8.0	89.5	57.0
2nd Basin	3.83	21.1	8.0	89.5	57.0
2nd Basin	3.95	21.1	7.9	89.2	57.0
2nd Basin	4.05	21.1	7.9	89.0	57.0
2nd Basin	4.18	21.1	7.9	88.2	57.0
2nd Basin	4.32	21.0	7.7	86.2	57.0
2nd Basin	4.43	21.0	7.4	82.5	57.0
2nd Basin	4.54	20.8	6.6	74.3	58.0
2nd Basin	4.64	20.6	5.5	61.1	60.0
2nd Basin	4.74	20.2	4.3	47.8	62.0
2nd Basin	4.87	19.7	3.4	36.8	65.0
2nd Basin	5.02	19.3	2.8	30.1	67.0
2nd Basin	5.15	18.9	2.4	25.5	68.0
2nd Basin	5.26	18.6	2.1	22.6	68.0
2nd Basin	5.37	18.3	1.9	19.7	69.0
2nd Basin	5.48	18.0	1.6	17.3	70.0
2nd Basin	5.60	17.5	1.4	15.0	73.0
2nd Basin	5.75	17.0	1.3	12.9	88.0

APPENDIX C

DETERMINING WATER QUALITY CHANGES AND TRENDS

Box and Whisker Plots

Quick Overview:

The 2009 summary **New Hampshire Lakes Lay Monitoring Program (NH LLMP)** reports include *box-and-whisker* plots that provide a visual representation of how the data are spread out and how much variation exists. Thus, the *box-and-whisker* plots provide a summary of how your data are distributed and provide a visual summary of how the data have varied among years and, when multiple sampling locations are monitored, provide a summary of how the data vary among sampling sites.

Basically, these plots show how the data group together for a given year. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. An algae bloom event may cause this type of outlier to occur in the chlorophyll data (high point) or Secchi disk clarity (low point).

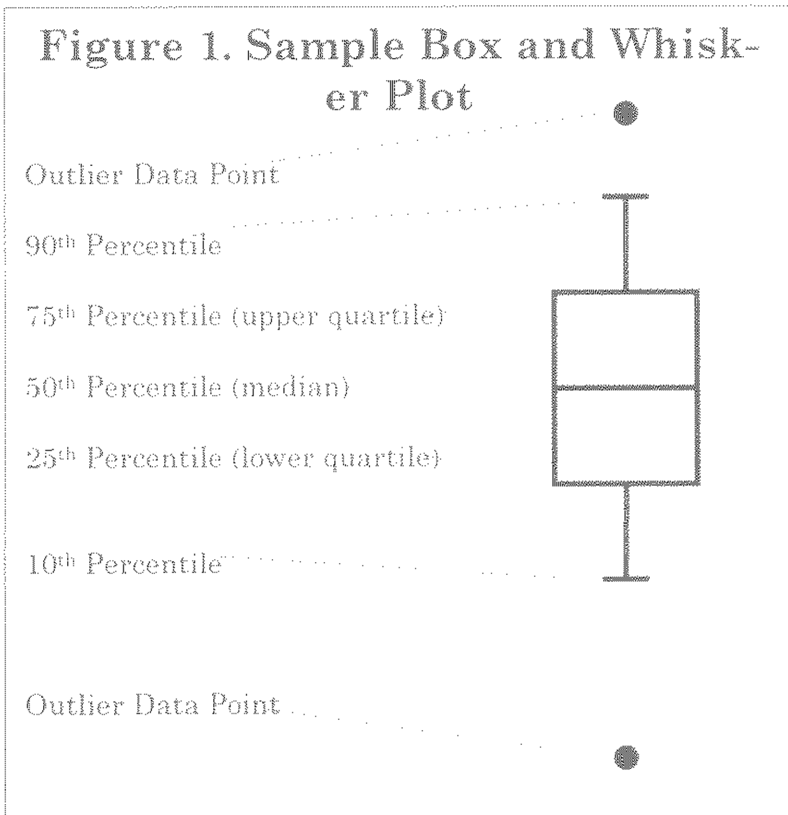
We recommend that each **NH LLMP** participating group plan on collecting weekly or biweekly measurements throughout the sampling season to ensure that enough data are available for this type of statistical analysis. We suggest that at least 8 data collections per year occur and generally set 10 measurements per year as a sampling effort goal per site.

We can employ the appropriate statistical techniques for detecting the extent that change is occurring when the sampling effort recommendations are followed. Your report summary should include box and whisker plots as well as a basic interpretation for your lake. If you have additional questions on interpreting your results feel free to call the Educational Program Coordinator (Bob Craycraft) at 603-862-3696.

The Details:

In the sections below we further describe the use of the box and whisker plot for those that are interested on how they are determined and how they are interpreted:

The **box-and-whisker plot** is good at showing the **extreme values** and the range of middle values of your data (Figure 1). The box depicts the middle values of a variable, while the **whiskers** stretch to demonstrate the values between which 80% of the data points will fall. The filled circles then reflect the "outlier" data points that fall outside of the whiskers and reflect values that are atypically high or atypically low relative to the other data measured for a given year.



The box-and-whisker plots can be summarized as a graphic that displays the following important features of the data when they are arranged in order from least to greatest:

- Median (50th percentile) – the middle of the data
- Lower Quartile (25th percentile) – the point below which 25% of the data points are located.
- Upper Quartile (75th percentile) – the point below which 75% of the data points are located.
- 90th Percentile – the point below which 90% of the data points are located.
- 10th Percentile – the point below which 10% of the data points are located.
- Outlier Data points – data points that represent the upper 10% or the lowest 10% of the data collected for a specific year.

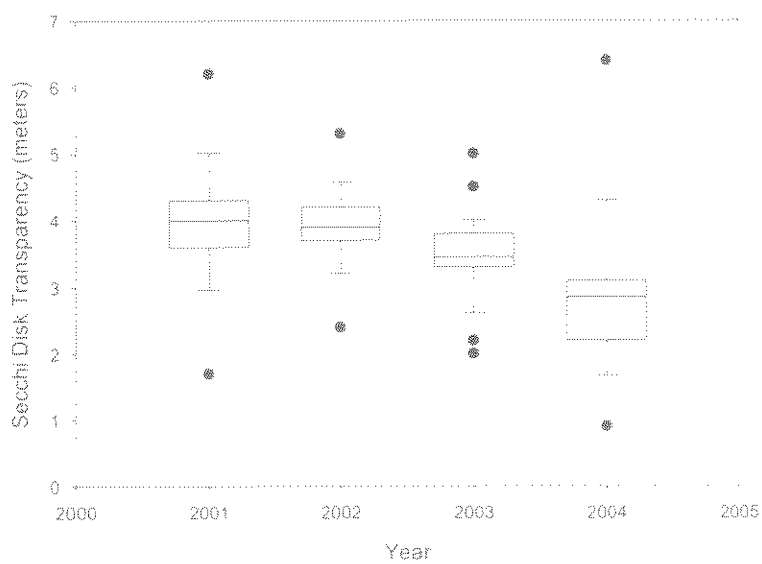
Note: A minimum number of data points is required to compute each feature documented above. At least three points are required to compute the Lower and the Upper Quartiles, five points are needed to compute the 10th percentile, and six points are needed to compute the 90th percentile. In the event that insufficient data points have been collected features will not be graphed due to the inability to reliably calculate the respective attribute.

Sample box-and-whisker plot interpretation:

A sample *box-and-whisker* plot is depicted in Figure 2 and it provides an opportunity to assess the usefulness of this type of plot at interpreting water quality monitoring data. The imaginary data depicted in Figure 2 reflect the annual water transparency measurements between the years 2001 and 2004. As you can glean from Figure 2, the distribution of the water clarity measurements have shifted to less clear conditions between 2001 and 2004. The median values, as well as the upper and lower quartiles (what is represented by the gray shaded box) have gradually shifted to less clear conditions over the four year span. The data points that lie between the upper and lower quartiles reflect 50% of the data collected for a given year and can provide insight into whether or not the water quality data are varying significantly between or among years. In extreme cases, when the gray shaded regions do not overlap between successive years or among years, one can quickly determine that the data distribution is significantly different for those years where the middle data (gray shading) does not overlap. Such differences can reflect long-term trends or can be a reflection of extreme climatic conditions for a given year such as atypically wet or atypically dry conditions that can have a profound impact on water quality.

Figure 2.

Sample Lake - Site 1 Deep
Annual Secchi Disk Transparency Comparisions
Box and Whisker Plots: 2001-2004



Note: The number of outlier data points is dependant on the size of the dataset.

Additional evaluation of the data can include a review of the 10th and the 90th percentiles (the whiskers) that provide additional insight into the distribution of the data. In this case, the trends exhibited by the 10th and the 90th percentiles are following the pattern of decreasing Secchi Disk Transparency as is exhibited by boxes (gray shaded regions). Outlier data points that fall outside of the "whiskers" can also be insightful. Such extreme values can be an early indicator of coming trends or can be an early warning sign of potential water quality problems. For instance, when Secchi Disk transparency measurements occasionally become significantly reduced (i.e. shallower water) such phenomenon can be an indication of short-term water quality problems such as excessive sediment or an algal bloom. If such problems are not contended with, but are instead left unattended, the longer-term impact could result in an increase in the magnitude and frequency of the water transparency reductions that, in turn, would result in a decreasing trend as evidenced by a shift of the "Boxes" to shallower water transparencies. There might also be occasions when the Secchi Disk transparency outliers reflect atypically clear water clarity. Such outliers can be a sign that conditions are improving or, as is often the case, the water quality is responding to short-term climatic variations that can have a profound impact on the water quality data. For instance, the outlier data point of 6.4 meters that was documented in 2004 (Figure 2) is counter intuitive to the long term trend of decreasing water quality. Plausible explanations for such an anomaly could be due to short term overgrazing of algae by zooplankton (typical for moderate to highly productive lakes), an abrupt shift in climate that might have favored clearer water (cloudy days or cooler water) or perhaps there was some sort of human intervention, such as a fish stocking or lake treatment that would have resulted in clearer water claries.

Your 2009 executive summary in this report includes a basic interpretation of the box-and whisker plots that are specific to your lake. However, since you have personal knowledge of the conditions of your lake and local events that might influence the water quality measurements, you might have additional insight into the cause of the water quality fluctuations that have not been discussed in the report. Should you want to discuss the water quality results further, or provide additional information that you feel is important, please contact Bob Craycraft by phone, (603) 862-3696, or by email, bob.craycraft@unh.edu.

APPENDIX D

GLOSSARY OF LIMNOLOGICAL TERMS

Aerobe- Organisms requiring oxygen for life. All animals, most algae and some bacteria require oxygen for respiration.

Algae- See phytoplankton.

Alkalinity- Total concentration of bicarbonate and hydroxide ions (in most lakes).

Anaerobe- Organisms not requiring oxygen for life. Some algae and many bacteria are able to respire or ferment without using oxygen.

Anoxic- A system lacking oxygen, therefore incapable of supporting the most common kind of biological respiration, or of supporting oxygen-demanding chemical reactions. The deeper waters of a lake may become anoxic if there are many organisms depleting oxygen via respiration, and there is little or no replenishment of oxygen from photosynthesis or from the atmosphere.

Benthic- Referring to the bottom sediments.

Bacterioplankton- Bacteria adapted to the "open water" or "planktonic" zone of lakes, adapted for many specialized habitats and include groups that can use the sun's energy (phytoplankton), some that can use the energy locked in sulfur or iron, and others that gain energy by decomposing dead material.

Bicarbonate- The most important ion (chemical) involved in the buffering system of New Hampshire lakes.

Buffering- The capacity of lakewater to absorb acid with a minimal change in the pH. In New Hampshire the chemical responsible for buffering is the bicarbonate ion. (See pH.)

Chloride- One of the components of salts dissolved in lakewater. Generally the most abundant ion in New Hampshire lakewater, it may be used as an indicator of raw sewage or of road salt.

Chlorophyll a- The main green pigment in plants. The concentration of chlorophyll *a* in lakewater is often used as an indicator of algal abundance.

Circulation- The period during spring and fall when the combination of low water temperature and wind cause the water column to mix freely over its entire depth.

Density- The weight per volume of a substance. The more dense an object, the heavier it feels. Low-density liquids will float on higher-density liquids.

Dimictic- The thermal pattern of lakes where the lake circulates, or mixes, twice a year. Other patterns such as polymictic (many periods of circulation per year) are uncommon in New Hampshire. (See also meromictic and holomictic).

Dystrophy- The lake trophic state in which the lakewater is highly stained with humic acids (reddish brown or yellow stain) and has low productivity. Chlorophyll *a* concentration may be low or high.

Epilimnion- The uppermost layer of water during periods of thermal stratification. (See lake diagram).

Eutrophy- The lake trophic state in which algal production is high. Associated with eutrophy is low Secchi Disk depth, high chlorophyll *a*, and high total phosphorus. From an esthetic viewpoint these lakes are "bad" because water clarity is low, aquatic plants are often found in abundance, and cold-water fish such as trout and salmon are usually not present. A good aspect of eutrophic lakes is their high productivity in terms of warm-water fish such as bass, pickerel, and perch.

Free CO2- Carbon dioxide that is not combined chemically with lake water or any other substances. It is produced by respiration, and is used by plants and bacteria for photosynthesis.

Holomixis- The condition where the entire lake is free to circulate during periods of overturn. (See meromixis.)

Humic Acids- Dissolved organic compounds released from decomposition of plant leaves and stems. Humic acids are red, brown, or yellow in color and are present in nearly all lakes in New Hampshire. Humic acids are consumed only by fungi, and thus are relatively resistant to biological decomposition.

Hydrogen Ion- The "acid" ion, present in small amounts even in distilled water, but contributed to rain-water by atmospheric processes, to ground-water by soils, and to lakewater by biological organisms and sediments. The active component of "acid rain". See also "pH" the symbolic value inversely and exponentially related to the hydrogen ion.

Hypolimnion- The deepest layer of lakewater during periods of thermal stratification. (See lake diagram)

Lake- Any "inland" body of relatively "standing" water. Includes many synonyms such as ponds, tarns, loches, billabongs, bogs, marshes, etc.

Lake Morphology- The shape and size of a lake and its basin.

Littoral- The area of a lake shallow enough for submerged aquatic plants to grow.

Meromixis- The condition where the entire lake fails to circulate to its deepest points; caused by a high concentration of salt in the deeper waters, and by peculiar landscapes (small deep lakes surrounded by hills and/or forests. (Contrast holomixis.)

Mesotrophy- The lake trophic state intermediate between oligotrophy and eutrophy. Algal production is moderate, and chlorophyll *a*, Secchi Disk depth, and total phosphorus are also moderate. These lakes are esthetically "fair" but not as good as oligotrophic lakes.

Metalimnion- The "middle" layer of the lake during periods of summer thermal stratification. Usually defined as the region where the water temperature changes at least one degree per meter depth. Also called the thermocline.

Mixis- Periods of lakewater mixing or circulation.

Mixotrophy- The lake condition where the water is highly stained with humic acids, but algal production and chlorophyll *a* values are also high.

Oligotrophy- The lake trophic state where algal production is low, Secchi Disk depth is deep, and chlorophyll *a* and total phosphorus are low. Esthetically these lakes are the "best" because they are clear and have a minimum of algae and aquatic plants. Deep oligotrophic lakes can usually support cold-water fish such as lake trout and land-locked salmon.

Overturn- See circulation or mixis

pH- A measure of the hydrogen ion concentration of a liquid. For every decrease of 1 pH unit, the hydrogen ion concentration increases 10 times. Symbolically, the pH value is the "negative logarithm" of the hydrogen ion concentration. For example, a pH of 5 represents a hydrogen ion concentration of 10^{-5} molar. [Please thank the chemists for this lovely symbolism -- and ask them to explain it in lay terms!] In any event, the higher the pH value, the lower the hydrogen ion concentration. The range is 0 to 14, with 7 being neutral 1 denoting high acid condition and 14 denoting very basic condition.

Photosynthesis- The process by which plants convert the inorganic substances carbon dioxide and water into organic glucose (sugar) and oxygen using sunlight as the energy source. Glucose is an energy source for growth, reproduction, and maintenance of almost all life forms.

Phytoplankton- Microscopic algae which are suspended in the "open water" zone of lakes and ponds. A major source of food for zooplankton. Common examples include: diatoms, euglenoids, dinoflagellates, and many others. Usually included are the blue-green bacteria.

Parts per million- Also known as "ppm". This is a method of expressing the amount of one substance (solute) dissolved in another (solvent). For example, a solution with 10 ppm of oxygen has 10 pounds of oxygen for every 999,990 pounds (500 tons) of water. Domestic sewage usually contains from 2 to 10 ppm phosphorus.

Parts per billion-Also known as "ppb". This is only 1/1000 of ppm, therefore much less concentrated. As little as 1 ppb of phosphorus will sustain growth of algae. As little as 10 ppb phosphorus will cause algal blooms! Think of the ratio as 1 milligram (1/28000 of an ounce) of phosphorus in 25 barrels of water (55 gallon drums)! Or, 1 gallon of septic waste diluted into 10,000 gallons of lakewater. It adds up fast!

Plankton- Community of microorganisms that live suspended in the water column, not attached to the bottom sediments or aquatic plants. See also "bacterioplankton" (bacteria), "phytoplankton" (algae) and "zooplankton" (microcrustaceans and rotifers).

Saturated- When a solute (such as water) has dissolved all of a substance that it can. For example, if you add table salt to water, a point is reached where any additional salt fails to dissolve. The water is then said to be saturated with table salt. In lakewater, gaseous oxygen can dissolve, but eventually the water becomes saturated with oxygen if exposed sufficiently long to the atmosphere or another source of oxygen.

Specific Conductivity- A measure of the amount of salt present in lakewater. As the salt concentration increases, so does the specific conductivity (electrical conductivity).

Stratum- A layer or "blanket". Can be used to refer to one of the major layers of lakewater such as the epilimnion, or to any layers of organisms or chemicals that may be present in a lake.

Thermal Stratification- The process by which layers are built up in the lake due to heating by the sun and partial mixing by wind.

Thermocline- Region of temperature change. (See metalimnion.)

Total Phosphorus- A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissolved), and chemically combined form (as in living tissue, or in dead but suspended organisms).

Trophic Status- A classification system placing lakes into similar groups according to their amount of algal production. (See Oligotrophy, Mesotrophy, Eutrophy, Mixotrophy, and Dystrophy for definitions of the major categories)

Z- A symbol used by limnologists as an abbreviation for depth.

Zooplankton- Microscopic animals in the planktonic community. Some are called "water fleas", but most are known by their scientific names. Scientific names include: *Daphnia*, *Cyclops*, *Bosmina*, and *Kellicottia*.